ELECTRO-PLATING VAT, AND SMEE BATTERY.

ELECTRO-PLATING

A PRACTICAL HANDBOOK

ON THE

·DEPOSITION OF COPPER, SILVER, NICKEL, GOLD, ALUMINIUM
BRASS, PLATINUM, ETC., ETC., WITH DESCRIPTIONS
OF THE CHEMICALS, MATERIALS, BATTERIES, AND
DYNAMO MACHINES USED IN THE ART

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Seventh Impression

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PREFACE

TO THE THIRD EDITION.

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A WORD or two as to the Author's aim in preparing this volume may prevent some misconceptions. It has not been sought to produce a text-book of Electro-metallurgy. The object in view has been to give in the plainest available wording the facts of every-day practice in an electro-plater's shop, and the work takes little account, accordingly, of the various theories of electrolysis. These, as a complex study in themselves, have been left to the text books. Electro-platers are too intelligent to neglect altogether the theories of electrolysis and electro-chemistry, but very few of them have the leisure to trench deeply into either of those branches of science. It has been sought in the following pages to help them in their work by getting directly at the every-day facts of successful practice in Electro-plating, and expressing these facts in a way easily understood.

Although the deposition of silver, gold, and other

metals is fully treated, special prominence has been
given to the very extensive business of nickel-
plating. Voltaic batteries as a source of electricity
are being superseded by dynamo-electric machines,
but it has been deemed advisable to retain in the
volume the descriptions of batteries that appeared
in the first and second editions. The section on
dynamos, however, has been re-written for the pre-
sent edition, and the chapter on dynamo-working
largely extended. The work has thus been brought
fully up to date.

The Author gratefully acknowledges the support
afforded him by the electro-platers of England and
America and other readers of the work in his
efforts to express a difficult subject in the plainest
language.

NOTE TO THE FIFTH EDITION.

The present edition is extended by an Appendix,
dealing with some of the more recent developments
of the nickel-plater's art.

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CHAPTER VI.

ELECTRO-PLATING.

CHAPTER I.

Introductory Remarks.

ELECTRO-PLATING is the art of coating metals with metals by means of electricity. Although the term is only generally applied to the coating of articles with silver, it is nevertheless quite applicable to the covering of metals with gold, nickel, copper, or other metal.

ELECTROTYPING is the second great division of the art of electro-metallurgy. It means the production of copper *copies* of articles by means of electricity.

The whole art of electro-metallurgy is based upon a simple fact—that a current of electricity tends to decompose a metallic solution into its constituents, depositing the metal upon any surface prepared to receive it. Solutions of almost all the useful metals may be thus decomposed, and the metallic portion thrown upon a receiving surface. This is the principle upon which both arts are based—they

owe their existence to the same fact. To *plate* is to perfectly clean a metallic surface, and to deposit the metal thereon, so that it may incorporate itself with the, original surface; the result is that the article looks like silver, copper, nickel, gold, or whatever metal may be deposited upon it. To electro*type* is to deposit the metal upon a surface prepared so that good adhesion cannot take place. The result is, that if the depositing is allowed to go on until a good thickness of metal is laid, the deposit may be removed. It will now have a separate existence of its own, and its face will faithfully represent the surface upon which it was laid.

(Electro-plating is thus applicable to the coating of all kinds of metallic articles, from a needle to a statue, either to protect the real surface from decay, or to beautify and ornament.)

Electrotyping renders easy the reproduction and multiplication of engraved steel plates, woodcuts, set-up type, printing surfaces generally, objects of art, hollow and solid vessels, coins, and various other things of more or less importance.

Both arts are practised to a very considerable extent in all civilised countries, especially in England—their birthplace—France, and America. There are large factories with every necessary appliance, and unwholesome dens where work is done by makeshifts, for the prosecution of electro-plating. The printer and engraver use electro-typing, and its applicability is extending daily. (Tons of objects—articles of utility and no use—are

made—which would not be saleable were it not for· electro-plating. A watch-case of copper is made to look like gold—for several years—for three shillings; a chain for two; scarf-pins at as much a dozen; hair-pins per gross. Forks and knives, spoons and liqueur-labels are silvered at threepence to a shilling each; teapots, coffee-pots, and other large things at five shillings each.）

One woodcut may be copied by thousands in copper. Engraved plates may be similarly reproduced, and the exceeding accuracy of the copy is such that a practised eye cannot find a difference between the copy and the original. All printing faces so produced may be made to withstand wear by thinly coating again with very hard iron ("steel-facing"), and dissolving this off, with further plating, when it is worn. Works of the most complicated design, undercut or plain, hollow or solid,—statues, large or small,—are produced and multiplied to any required extent.

By simply immersing articles in solutions, they are coated thinly with metals; large articles at so much each, and small at so much per dozen or pound.

The art of electro-deposition is still further divisible into several sections. In electro-plating there is first to be considered the

Solution : it must be composed of a salt or compound of the required metal dissolved in water or other liquid. It is contained in a vat or pot termed the depositing vessel. Electricity must be made to

pass through this solution, from one plate to another.
The plate by which the current enters is called

The *Anode*, which is in most cases of the same
metal as the solution. This anode (*ana*, up, and
hodos, a way) not only serves to lead the current
into the solution, but it usually dissolves' just as
fast as the solution is robbed of metal, so that an
electro-plating solution is constantly renewed, and
made to last for several years. The current passes
through the solution, decomposes it, and deposits

(Depositing Cell.)   Fig. 1.   (Battery Cell.)
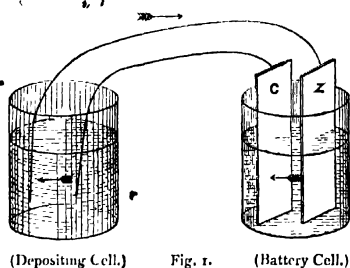
the metallic part upon the article being plated,
which is sometimes called

The *Cathode*—from *cata*, down, and *hodos*, a way.
The electricity passes out of the liquid by this plate
—teapot, bundle of pins, or whatever it may be—
back by stout wire to the

Battery, Fig. 1, where the electrical energy required
is generated. A battery, or generating cell, is not, as
is popularly supposed, a complicated chemical com-
bination. A good electrical generator may be made
from a pair of plates, zinc and copper for example,
plunged in soured or acidulated water. A battery

is a combination of two or more cells—the term is not properly applicable to one cell only. A wire stretches from each plate to each end of the depositing vessel, and is then cleanly connected to the anode and cathode, or article. This completes the arrangement, which is applicable either to plating or electrotyping if the solution is a copper one. But before anything can be done, the articles to be plated must be

Cleaned, which means absolute freeing from all possible impurities by chemical means. This is spoken of in the following pages under the head of *preparation,* which means the cleaning of articles, whether mechanical or chemical processes are used. It also includes the preparation of articles to be copied in copper, making moulds from the same, and preparing or rendering conductive the surfaces of such moulds. Under the head of electrotyping will be found all the necessary particulars, moulding and preparing, relating to it. *Preparation,* again, is devoted chiefly to the plating section of electro-deposition.

It will prove a great saving of time to the amateur or would-be plater to make a few experiments with a solution composed of sulphate of copper dissolved in warm water. The "battery" may be a copper and zinc pair, in a teacup full of acidulated water.

A knowledge of the fact that such simple cells must have their plates separated for a little distance by some non-conducting substance, such as wood, paper, or glass, is also necessary. It will, perhaps,

.be unnecessary to state that wood and such things will not conduct electricity, and that all metallic and most liquid substances conduct it very well. Metals—silver, copper, and so on—are good conductors; water not so good, damp wood or wire-covering poor, and dry wood and such non-metallic substances are so poor in conductive power that they are usually called *insulators*, or substances through which electricity cannot pass.

A Daniell or Smee generating cell (see *Batteries*), a pint of silver, gold, or copper solution, with an anode plate of the required metal, will enable the amateur to plate small articles, and also to electrotype in the copper solution. The Daniell or Smee generating cell will supply the electricity, a solution the metal, and all that is wanting is a surface to deposit it upon—permanently if for plating, and for the time being if for typing. Small articles, which it is required to coat only thinly, may be readily plated by simple immersion, or in contact with a chip of zinc. (See *Simple Immersion*, p. 116.) Solutions are described by means of which simple immersion may be made to give a good thick coating. Those who wish to earn their bread by silvering small articles cheaply, as thousands do in Birmingham and London, will find those simple-immersion mixtures very useful. The hot ones are best suited for rapid and good working. It is of more importance to very perfectly clean the articles to be *electro*-plated, than those to be silvered, coppered, or gilt, by simple immersion. The only

guarantee, however, of good work is the most scru-
pulous cleanliness: even the finger must not be
allowed to touch a surface cleaned. • In typing,
on the other hand, the face of the article to be
copied need not, and indeed must not, be made
clean if it is intended to deposit upon it direct,
which is seldom done. It is usual in typing to take
an impression of the article in gutta-percha, or
some other substance, and to render the resulting
surface conducting by applying various substances,
more. or less valuable in practice. Just as much
care is necessary to make a perfect conducting
surface upon a mould as to clean an article• for
perfect plating.

Owing to the fact that this treatise is written for
those who know nothing of chemistry or electrical
science, it is arranged in a somewhat unusual way ;
and explanations are given, and language used,
that may, to a great extent, be considered unneces-
sary by the initiated. Explanations of the terms
which could not well be avoided are given, and
their connection with the work of every-day life
shown. The reader is assured that the practice of
electro-deposition may be carried on with only a
modicum of scientific knowledge.

Explanations of Terms.

To "*dilute*," means in almost every•case to add
water to, or mix with water. Dilute acid means
usually acidulated water. Many mistake the term to
indicate acid to which a little water has been added.

To "dissolve" simply means to place the sub-
stance in some liquid by which it will be *melted*,
and disappear, and the liquid is then

A "Solution." 'Solutions are usually liquids,
such as water and acids, in which some solid sub-
stance or gas has been *dissolved*.

To "Digest" is to dissolve, but it usually means
by *heat*—that is, the liquid must be heated, to
slowly dissolve the substance, and this is called
digestion.

To "Precipitate" is to *throw down* any metal or
substance in solution by the addition of another
substance—thus, to precipitate the silver of a solu-
tion as a chloride, add hydrochloric acid or common
salt. *The* precipitate means the substance thrown
down.   Precipitates are usually heavy enough to
fall at once to the bottom; from them the solutions
are then

"Decanted." To decant may mean *pouring off*,
or it may mean drawing off with a syphon. 'It is
not unusual then to

Redissolve the precipitate—this, of course, means
dissolving again, but

Precipitate and Redissolve generally mean to
add such an agent as a solution of potassium
cyanide to a solution, and to continue adding it
until the precipitate which is formed has entirely
vanished, by reason of the great strength of the
added agent.

Evaporate almost always means to *boil* the solution
until all the liquid portion disappears in steam, the

Residue or *resulting* substance being the metal or substance previously in the solution. This is driving off all

Excess of acid. Excess here means more than is sufficient to form the salt or other substance at the bottom of the vessel.

Evaporate nearly to dryness means to get rid of the liquid portion until the liquid left is very thick, and ready to crystallize on cooling. When directions are given to

Wash the resulting salt, it means that the salt is not soluble in water, otherwise it would dissolve in the water. When it is directed to

Wash the precipitate, it means that water is to be dashed in, the precipitate stirred in it, allowed to settle, and freed from the water by pouring off or

Filtering, which means that the whole, water and precipitate, is to be poured on a filter, usually of calico loosely stretched on a hoop.

Saturated solution, or *Saturation*, means that condition of a liquid when it *cannot dissolve any more* of a substance.

Free acid, or *Cyanide*. This means that amount of the cyanide added after the precipitate or substance is quite dissolved. It means more than enough to effect the immediate purpose. Free acid or cyanide in a solution for plating means that amount necessary to dissolve the anode, or, more correctly, to form into a salt the metal dissolved off the anode by the current. It also assists in keeping the conductivity of the solution good.

Salt means any compound of a metal, usually that resulting from its dissolution in an acid and subsequent crystallization. "Common salt" means chloride of sodium, or common house-salt.

Parts usually means weights and measures; and where "parts" is used in directing for the make-up of solutions it means that grains, ounces, or pounds may be used, or ounces, quarts, and gallons, according to the volume of solution required.

Deposit, "depositing," "coat," "layer," "covering," mean simply the metal thrown upon any article or surface by the aid of electricity.

Plating is used here to indicate not only coating with silver, but with all other metals.

Clean. This is a very important word to understand. As is said in the section on preparation, it means *absolute* freedom from all foreign substances, even a film of air. Chemically clean is perfectly clean.

Film means the coating or deposit. In any other sense its meaning will be obvious.

Amalgamate means to cover with a closely adherent film of *mercury.*

Quick means to coat with mercury in a solution of a mercury salt.

Contact. This means electrical contact, or the completion of an electrical circuit. It means the parts touched together to complete a circuit, or, in other words, to complete a metallic path for the passage of electricity.

Connection. 'This means joining a wire or other conductor to complete a circuit. It means also that the parts of the metals touched together must be clean, because electricity will not pass through dirt. " Connect to " means to join to with wires to form a proper conducting

Circuit. This means the path or conductor in which electricity passes. A *complete* circuit of some good conductors is necessary, because electricity must find its way, so to speak, *back* to the battery or other generator after doing the work.

" *Work.*" This usually means the articles to be plated; again it means the duty performed by the current of electricity.

"*Pole*" means one of the extremities of a battery, or one of the plates of a single cell. (See Fig. 1, p. 4.) The words "positive pole" and "negative pole" are frequently used in treatises on electro-metallurgy. In the battery the zinc plate slowly dissolves. It can be shown that the electrical action resulting therefrom moves *through the liquid* towards the copper plate, from the upper extremity of which it may be led by conducting wire back to the zinc plate. Hence, since the copper plate might be ·called the giver and the zinc plate the receiver, their extremities are respectively regarded as positive and negative. In reading other books, the plater will find the zinc *plate* called the *positive plate*, but the end of this plate, or its wire, the *negative* pole or wire. He will also find the copper plate called negative, and its end cr wire positive.

A little, consideration will show that these terms
are scientific and perfectly logical. The current
of electricity is generated or set free at the *zinc*
plate, and instead of passing off by the zinc con-
ductor, it passes *through the solution* to the copper
plate, which receives it, and is therefore termed
negative, while the zinc which gave rise to it is
called positive. The current then passes off by the
copper conductor, which *leads towards* the zinc, and
is therefore termed the positive pole or wire, while
the zinc plate, which *receives* the current from the *out-
side circuit*, correctly enough is known as negative.

"*Cell*" means a pair of plates in a solution or
liquid; a generator of electricity, such as a zinc and
silver plate in acidulated water. The plates should
be as near together as possible without touching.
Element is the same thing, or one cell of a

"*Battery*," which is a combination of cells, al-
though the term is sometimes, though incorrectly,
used for one cell only.

Join up, means to connect together, either in
series—zinc copper, zinc copper—or in "multiple
arc," which is joining all the zincs to one con-
ductor, and all the coppers, carbons, or silvers to
the other. It also means to connect work so as to
put it

In the circuit, which means to so join the wires
that the electricity must pass through the required
part.

To solder means to clean, wet with hydrochloric
acid saturated with zinc, place tinman's solder

upon, and heat until it runs and *takes* to the metal
to form a perfect metallic joint. Soldering is best
done with a *soldering bolt* of copper, heated, and its
end cleaned and "tinned" with solder.

Stripping means the process of taking valuable
or other metals off old or badly-plated goods.

Current means the *volume* of electrical action, or
energy passing, with no reference to its electro
motive force.

Force of current is more fully explained in the
section on batteries; it means the strength to *push*
through resistance.

Resistance, of course, means the imperfect con-
ductivity of the solutions, by reason of which they
resist the passage of all electricity of insufficient
force.

Insulator means that through which electricity
cannot pass, or a *very imperfect* conductor. Insu-
lated means covered with a very badly conducting
substance—thus an insulated conductor is a copper
wire covered with gutta-percha, cotton, or silk.

Conductor means a wire leading the current.
These wires should be of stout copper, and covered
with gutta-percha or other insulator.

Wires are conductors. They should always be
insulated.

To wire is to join the articles by wire so that the
current may pass through them.

Anode means any plate in a solution connected
to the copper or positive wire. Anodes in solutions
are meant both to conduct the current there, and

to dissolve, so as to make up for the metal deposited
upon the

Cathode, which is the article connected to the
wire leading from the zinc plate.

Galvanometer, an instrument consisting of a coil.
of wire with a freely suspended compass needle
therein, for measuring the force of electricity, or
indicating by the swing of the needle its direction
of motion. (See *Galvanometer.*)

CHAPTER II

Practical Work.

THE *plating shop* should be well lighted, and cleanly whitewashed. It should be on the ground floor, and steam power is a great aid to rapid and good working. If there are dynamo-electric machines instead of batteries, they should be raised three feet from the ground to allow satisfactory examination of their commutators. Vats should be placed against the wall, if possible under a window with a white screen, to be used for strong sunlight when necessary. Scratch-brushing arrangements, with the cleaning pots, should be at the other end, and nearest to the door. Gilding being a part of the business not so extensively applicable as silvering, nickeling, and coppering, should, on account of the valuable metal, be done in a more private room, fitted with gas or other heating arrangements. Whether for gilding or coppering, the temperature of the shop should never fall below 45° Fahr. in winter, because almost all solutions work badly at a low temperature; and if batteries are kept out of the room, they must not be allowed

to freeze. Good ventilation is of the greatest
importance. There should be a yard or roofless
place in which to do stinking chemical operations,
and a plentiful supply of tap and filtered rain
water.

Heat should be at hand, preferably by means of
steam pipes. Over this heat should be kept iron
boxes filled with boxwood or mahogany sawdust
for drying the articles. An iron boiler, for holding
the hot caustic potash cleaning mixture, should be
out of doors. No cleaning arrangements should
be carried on near to the dynamo-electric machine,
or engine. Two tubs should contain dipping
water, and the cleaning and "pickling" and
"quicking" mixtures should be in glazed earthen-
ware pots. Chemicals should be kept upon shelves,
which should be fitted with a dark cupboard for those
materials that will not bear exposure to the light.

And finally, but of the greatest importance, there
should be a supply of acetate of iron as an antidote
in case of poisoning by the cyanide liquids so much
used. (See p. 39.)

Scratch-brushes.—The operation of scratch-brush-
ing is very often spoken of throughout this treatise.
Scratch-brushing means rubbing with fine *wire*
brushes and some liquid, to smooth or rub off the
dull deposit on goods before they can be properly
finished for burnishing. The term is also applied
to a similar action with hard hair-brushes used for
cleaning the articles prior to their being plated.
The simplest scratch-brush is simply a bundle of

fine wires, usually brass, about an inch in diameter and five long. It is bound tightly by much stouter wire, which is wound off as the brush is worn (Fig. 2).

. Scratch-brushes for large and professional work are always mounted on a lathe-frame, or in such a way that steam power or the foot may be used to give a rotatory motion to them. The brushes are thin circular ones of brass or steel wire (Fig. 3). For power, the brush is simply mounted upon a spindle running in two bearings, a pulley being provided to take the belt from the shaft overhead. The lathe contrivance is always a rough framework, with a wheel and treadle. A hood of sheet metal is provided over the brush, to prevent its throwing the dirt in showers about the shop. It is usual to feed the brush with a continuous drip of stale beer, supplied from a small barrel overhead. There

Fig. 2.—Simple Scratch-brush.

is also a trough under the brush, and a drain-pipe to take off the used drippings (Fig. 4).

Vats for Solutions—Depositing Vessels.—The size of the vat will depend upon the magnitude of operations. Large vats contain as much as 300 gallons of the solution, others 150 and 200 gallons. Such vats may be from three to six feet long, from

Fig. 3.—Rotary Scratch-brush.

one to two wide and deep. The actual size, so long

as it will hold the articles to be worked upon, is of
little consequence.   It is usual to have the long
vats filled with a series of anodes, connected to one
battery, between which the articles are immersed,
so that both sides of them may be equally plated
upon.

Wooden vats without lining used to be employed,
but experience has shown that they absorb much
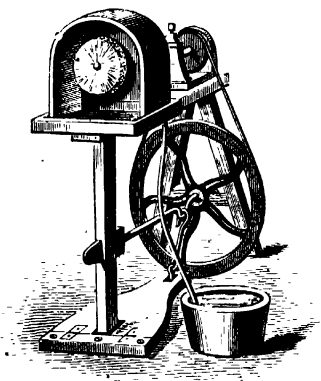
Fig. 4 —Scratch-Brush Lathe.

of the liquid, and if it is valuable, as silver, the
fault is a great one.   For all solutions they ought
to be coated within.   Gutta-percha will not do for
cyanide liquids, as they destroy it.   Vats made of
wood are best lined with good Portland cement.
But no vat is so good as one of rolled iron plate,
with a lining of thin wood to prevent contact with
the anodes. All the first plating factories have iron

vats, and the best of them are enamelled within, which makes the vessel perfect, if it is properly done. Small tanks for gilding made in this way are very handy.

For sulphate of copper solutions a wooden vat does very well, and it is much better lined with marine glue or asphaltum cement.

Cyanide liquids, except of course gold ones, which require to be heated, may be kept in well-jointed oak tanks, but the wood is gradually destroyed, and the solutions soak through and run off on the outside. A wooden tank lined with slate bedded in cement gives every satisfaction.

For the standard nickel solution a tank of wood lined with asphaltum cement gives every satisfaction.

Gilding solutions should be in iron enamelled small tanks, fitted with feet, and with gas-burners, lamp, or stove beneath ; and a thermometer ought to be permanently fixed to the tank, below the surface, so that the temperature may be ascertained at any time, and regulated.

Contact arrangements are best made with stout brass tubing. Every tank of large size, or which is to have over one anode, should be well fitted, to save trouble, with " continuous contact" arrangements. Every tank should, for the same reason, have a ledging extending outwards. Upon this ledge the "continuous contacts" are laid. They are simply two rectangles of brass tubing. One rectangle goes all round the outside of the ledge, on the upper surface, and to this the copper or

anode wire is fixed by a binding screw. And from
side to side of the tank extend the anode rods,
resting upon this rectangle of tubing.

Inside this runs another rectangle of smaller
tubing, to which the zinc or negative wire is fast-
ened, and across this rest the three or four article
bars used. These bars should have wooden or
gutta-percha heads, so that accidental contact with
the anode rectangle may be avoided. It will be
seen that the arrangements are of a very simple
description.

The brass rims and rods must be kept clean,
throughout their lengths, and for this purpose
emery-cloth should be at hand and used every
morning. It is a great improvement to gild the
rods, which will render the cleaning unnecessary,
unless extreme carelessness is used. It is a good
plan to have a slit made in the wooden rim, be-
tween the rectangles of tubing, and the edges
sloped off to it, but no iron or other metallic con-
tacts may, of course, come between the rods or
tubes. This slit will carry off any liquid that may
be by accident spilt upon the ledging. Such parts
should be kept dry, because a layer of liquid con-
necting the tubes or rods will "short circuit" most
of the current, and send it back to the battery
without passing through the liquid. Arrangements
may of course be, and are, adopted to prevent any-
thing of the kind, such as wooden corner supports
for the larger rectangle of tubing.

For smaller tanks or vessels, such as are used

for gilding, it will be unnecessary to provide con-. tinuous contacts, because one anode is usually enough. A pair of rods with wooden ends, for resting upon the tank to quite prevent contact, will be enough. They should have binding screws fitted to them, and from them should hang, by stout hooks, the anode and batch of articles being gilded.

Operations on a still smaller scale need not involve the providing of rods. The anode may be simply hung from the copper wire, and the articles from the zinc wire. This is applicable to small working in porcelain vessels. A great deal of good gilding is done in such things as large battery pots, heated by being kept in boiling water in an iron pan, glue-pot fashion, and no other arrangements are employed.

In all cases where the anodes are over six inches square, they should be provided with *two* silvered or gilded hooks to hang evenly upon the cross-rod.

It is very convenient to have a let-out tap fitted to tanks two inches above the bottom, for letting off liquids; but some platers would prefer to employ a syphon of lead tubing, and draw off from the top.

.Preparation of the Articles.

I cannot impress too strongly upon the beginner the importance of properly preparing the articles before plating them with any metal. We must have *chemically clean* surfaces. *Ordinary cleanliness* is of no use whatever.

To sum up the causes of failure in almost every

, instance of bad work in one word, is no difficult matter—that word is *dirt*. No matter how clean a surface may *look*, it is in most cases dirty, and if it is not dirty, there exists upon it a film of air, which will effectually prevent good coating from being done. It is to the plater absurd to suppose that, because the amateur cleans his watch-chain with whiting, it will take a coating that will stand heating or burnishing. Common cleanliness causes the work to be a failure, because, if there is not an invisible coating of oxide or dirt, there is one of air, which must be removed effectually before any-' thing can be done. It is a very easy matter to obtain a deposit over the surface, but quite a different matter to lay one that will stand burnishing and heating. It is, moreover, important in good work to make the surface smooth.

The mode of operation in cleaning will depend upon the nature of the article, and its condition. To " rough clean " the surfaces when they are very dirty, a hard hand-brush, with silver sand and water, will prove useful. After this, as a rule, the article should be well scratch-brushed to clean and smooth the surface, but small articles of silver may be brushed with a tooth-brush and rouge, whiting, rotten-stone, and other cleaning powders, until the rough and dirty superficial coating is cleared off. Articles that appear perfectly smooth and clean will, in most cases, have a slightly greasy surface, which must be cleaned off by rinsing in boiling caustic potash solution.

Rough, and coated with Oxide.—Scrub off with hard brush, sand and water, emery-cloth, scraper, fine file, or wire card, according to the size and condition of the articles—this applies to old articles. After finishing the surface with the scratch-brush and stale ale, burnish if required, and treat as hereafter directed.

Burnishing.—This is rubbing in straight lines with a finely polished hard steel tool, long, and of oval section. Burnishers of other materials, such as dogs' teeth and agate, are also employed. Burnishers are made for different purposes; for large work, to be fixed in the vice, the burnisher is an oval bar of hard and finely polished steel, about a foot long, and having two handles. For work revolving in the lathe, the burnisher is a rounded head upon a steel shank; the head being finely polished is pressed upwards upon the work, and moved from end to end of it. With brass this is done dry, but with copper and iron a little soap and water will be found useful to prevent the tool from cutting up the work. For hand work nothing is more suitable than the ordinary watchmakers' or jewellers' long burnishers, costing a few pence. All these tools must be kept brightly polished by rubbing in straight lines upon the finest emery-cloth. The operation of burnishing is not learnt at once, it needs attention and practice. The surface must be previously prepared, by scratch-brushing, or fine draw-filing, or rubbing in straight lines with emery-cloth, and then the burnishing

may be done. The work must be held firmly, and soapy water used, if the tool begins to grate upon the work. Burnishing is also done to the coatings after they are laid, if a polished appearance is required. But it should be remembered that the best electro-plate, whether nickeled or silvered, is not burnished, except to ornament prominent parts. The work is smoothed and *buffed*, that is scratch-brushed, and then dried and held against a revolving buff, or softly covered wheel, making use of such powder as fine jewellers' rouge. A first-rate buff may be made by placing a great number of fustian discs, cut circularly and pressed against a flange mounted upon a spindle—a wheel, in short, of discs of cloth. Hand buffing may be done with wood sticks covered tightly with two layers of wash-leather or fustian, employing rouge to polish with. Rough cutting materials must not be employed to clean electro-plated surfaces.

Manufactured Goods.—These are the articles as they come from the maker's hands, clean apparently, but covered with a greasy film. They must be rinsed in the boiling caustic potash liquid, and then treated like others by dipping in various cleaning mixtures, of which particulars are here given.

Scoured and buffed articles of silver are to be rinsed in diluted nitric acid, dipped for a moment only in strong acid, swilled in water, and at once put in the plating vessel. *Great care must be taken not to touch any cleaned surface with even one finger ;*

if this is done, the deposit *will not adhere* to the spot.

Copper, German-silver, and *brass,* or which metals the greater number of articles are made, are to be prepared for the bath, after scratch-brushing, by immersing in a pickle made by mixing together, half a gallon of each, water and sulphuric acid, a quart of nitric acid of ordinary quality, and two ounces of hydrochloric acid. It is wise to have at hand two vessels of this cleaning mixture; one quite fresh for the final dip before swilling in water and placing in the vat, and the other in which to first dip and clean the articles. The articles should be kept for a minute or so in the first liquid, and if necessary rubbed with it by a pad of cotton on a stick. The final dip is only momentary. A rinse in water finishes the work, which must be *instantly* placed in the depositing vessel. If articles are allowed to dry, they must be again dipped, or if the fingers touch them the same treatment will be necessary. All articles should have the suspension wires fixed to them *before* dipping.

Steel and iron articles, after scouring, are to be cleaned in a mixture of a pint of sulphuric acid, an ounce of each nitric and hydrochloric acids, in a gallon of water. The articles should be left in the solution for some time, and if exclusively for steel, the mixture should be weaker.

Tin, lead, pewter, and Britannia metal are to be cleaned by rinsing in the caustic potash solution, swilling in clean water, and at once put to plate

To make up the caustic potash solution, place in an iron boiler four pounds of caustic lime, add water with stirring until a creamy mixture is produced. Then stir in a solution composed of eight pounds of pearlash in hot water. Boil the mixture. If an exceedingly strong caustic alkali is required for extra dirty work, dissolve stick caustic potash in hot water. Care must, however, be taken to keep the naked skin from this material, because it produces exceedingly bad sores, which are difficult to heal. It will, in fact, dissolve the skin quite readily. (See *Chemicals*.)

Britannia metal, zinc, tin, and pewter should not be dipped in acid mixture, because they dissolve therein very fast. As soon as the "dipping" is done, it is best to have at hand either a stream of water, or water in two pots, so that the articles may get a washing and a final dip before placing in the depositing vessel. A great many of the articles have, however, to be dipped in a "quicking" solution to get a coating of mercury, to secure adhesion. (See *Quicking*.)

Cast iron, with the original "skin," is usually exceedingly hard, owing to a glaze of iron silicate. It is often treated with hydrofluoric acid—usually called "fluoric acid." This will dissolve the silica, but the greatest possible care is necessary in handling it, as it will not only destroy the human skin and make bad sores, but it will dissolve glass vessels, and must therefore be kept in a gutta-percha or lead bottle, closed with a stopper of

gutta-percha. Its fumes should be avoided as much as possible. It is usually employed for glass ornamenting, and lettering upon "flashed" glass.

In all the operations it is best to have at hand a strong cleaning solution, a medium one, and a "spent," or weak one, and then two pans of water for final dipping. The solutions are called "dipping liquid" for the strong, and "spent liquid" for the weak. Nitric acid, used chiefly for silver, is called aquafortis when in the strong state, and when weakened by repeated dipping, "strong pickle;" the second quality or strength of this being called "weak pickle." Pickle is also frequently applied to sulphuric acid water, into which articles are thrown after heating. Small bulks of the liquids never work well. They should be contained in large earthenware pots, well glazed; the caustic potash liquid in an iron vessel over a fire. Caustic potash is employed to clean off greasy surfaces, and the acid mixtures are usually made up to dissolve films of oxides, and to clean up or expose the real surface. It may be often unnecessary to scour or scratch-brush the work. The acid mixtures may do the cleaning throughout. Copper and German-silver are very often heated to dull redness, and then thrown into sulphuric acid pickle, which will cause the scale to fall cleanly off, when a final dip and wash will render the work ready for plating upon. Articles that are soldered with tin solder must not be so treated, because it would cause them to fall to

pieces. Silver may also be heated, and thrown into hot dilute sulphuric acid. Zinc may frequently be dipped in strong pickle—dilute sulphuric acid.

"Dipping acid," or nitric acid mixed with sulphuric, is sold at a cheap rate.

For coppering the cleaning itself will be sufficient to insure an adherent coating, but for silvering and gilding it is wise to employ the method of coating with mercury.

Quicking Articles.—The mercury solutions are easily made up and kept in order. For copper, brass, and German-silver make a solution as follows :—Prepare about a pound of nitric acid diluted with three times its volume of water. Pour this upon an ounce of mercury, a little at a time, with stirring, until all the metal is dissolved. The action will be somewhat slow, but no more acid than is necessary is to be added. Dilute the whole with a gallon of water. *Zinc* articles are best coated in a solution made up in this way :—Dissolve an ounce of nitrate of mercury in two gallons of water mixed with four ounces of sulphuric acid. To make a quicking solution of cyanide of mercury in potassium cyanide:—Dissolve the mercury in dilute nitric acid; make up a solution of cyanide of potassium one ounce to the pint, and add it to the mercury solution, with stirring, until the metal is precipitated as cyanide. Allow to settle, and pour off the liquid portion; wash with clean water, pour off, and add to the precipitate with stirring enough cyanide solution to dissolve it.' Dilute the whole to the ex-

tent of one ounce of mercury to a gallon and a half.

It is important that these solutions contain only enough mercury to give to the article the thinnest possible coating; a thick coating will cause the metal to strip after the plating is done, which is an exceedingly vexatious result. Too little, so long as the surface is perfectly covered, cannot possibly be put on, but too much is easily laid. A good test of a quicking liquid is to immerse in it a piece of clean copper plate. If the plate becomes white very soon, with a thin, closely adherent coating, the liquid is right. If the coating is black, or bad in colour, the liquid is not properly made, or is exhausted. It is important that all the articles look uniformly white on removal from the quicking vessel. If they are patched, the surface is either greasy, or the solution badly made. A good coating will insure that a perfectly reliable molecular contact will take place between the plating and the article, which will stand burnishing or other usage.

Preparing Iron for Silvering and Gilding.—It would appear quite impossible to get either gold or silver in good molecular contact with an *iron* surface, no matter how perfect the cleaning may be. A good deal of plating with silver has, however, been done upon iron direct, but the work is a botch at the best, because the metal will strip off very easily, and will not stand burnishing. On cutting under such a film, the metal may be *scaled*

off-with the knife, disclosing an iron surface far
from good in colour. However it happens, the
surface is of a bluish oxidized tint, although on
placing in the bath it was perfectly clean. This
tint seems to take some time to develop, because
it is seldom found directly after plating. The only
remedy as yet practically applied is to *deposit a
thin coat of copper* upon the iron previously to
gilding or silvering. Iron "takes" copper per-
fectly in a cyanide of copper solution. (See *Copper.*)
The copper should not have any appreciable thick-
ness, but must perfectly cover the iron.

Stopping off.—This is the prevention of a deposit
from spreading all over an article when only half
of it is to be plated. Melted solid paraffin is very
useful in cold liquids, acid or alkaline, because it
is not affected. Sealing-wax varnish may be used
in liquids not too hot. Copal varnish is, however,
more suitable for hot liquids. The best copal
varnish, with an admixture of fine jewellers' rouge,
will prove useful in extra hot liquids. (See *Gold*.)
Various cheap substances may be used for large
surfaces, but they must be fairly thick, and should
be capable of being easily dissolved or melted off
after the work is done. Engravers' wax may be
used, also tallow, bees'-wax, shellac varnish, and
such substances easily got rid of. Pitch or tar is
not fit for the purpose. Surfaces not to be deposited
upon should, if possible, be kept turned away from
the anode, or exposed to its influence as little as
possible, because deposits actually do take place

upon thin varnishes if the current is strong. This
is a waste of metal.

Dipping, for "Bright" and "Dead" Gilding.—
These appearances are chiefly applicable to copper,
brass, and German-silver. Dip in weak nitric acid
until the surface shows a black scaly appearance,
then immerse in " strong pickle "—very weak nitric
acid. Then plunge into strong nitric acid and
quickly wash, and put in the plating vessel. It is
more convenient, when there are many things to
do, to provide for " bright dipping " a mixture of
exhausted nitric acid, half a pound; water, one
pint; hydrochloric acid, three pounds. It is suited
to the general run of metals, copper, brass, and
German-silver. They are to be soaked for a few
minutes in it, after which they should look bright
on cleaning off the black slime covering them.
Such articles may be again prepared for the bath
by rapid and effectual washing.

" *Dead* " dipping is usually done in a mixture of
one pound of sulphuric acid, and two pounds of
ordinary commercial ("yellow ") nitric acid, with the
addition of two ounces of common salt. Soak the
articles in the mixture until "dead," remove and
pass through the pickles, then through two waters
to the plating vessel.

In all the processes of dipping to impart chemical
cleanliness of surface, small articles, or such as are
fitted for it, should be strung upon a wire in
bunches, or in stone vessels (Fig. 5), so that they
may be shaken about in the vessels. The same

wire should hold them in the gilding or silvering
vessel, and such wires should be already gilt or
silvered to prevent loss of contact. • Batches of
spoons and forks should be done at once, strung
upon a suitable wire by hooks made to slip over
their stems.

" *Wiring" the Articles.*—Small articles for gild-
ing are to be strung upon a thin gilt wire·if they
admit of this being done, and if not, they should be

placed in a stoneware basket, and
shaken about constantly while in
the gilding liquid. The contact is
got by wiring only one of the
articles to the article-rod of the
vessel, but almost all kinds of
small goods may be wired in
batches: if this is done they must
be arranged loosely, and constantly
shaken while being gilt, otherwise
they may only be partially gilt,
and the colour may be bad. (See

Fig. 5.—Dipping Ladlo
and Basket, of Stone-
ware.

Gold.) Larger articles should be
hung by stouter wires separately, and in order that
such wires do not receive a deposit also, they are
bent into suitable hooks at their lower ends, and
covered with a tube of good india-rubber. Varnish
will not do for the reason stated before—that metal
will be thrown upon thin coatings, attracted by the
metallic conductor within. These tubes should fit
the wires tightly, and bundles of such wires should
be at hand, with ends turned into all kinds of hooks

and loops, to suit the standard work doing. All such hooks ought to be gilt top and bottom, to insure good contact with the article-rod and articles.

For silver-plating, the same hooks covered upon their stems, should be at hand, especially those with right-angle loops at their lower end to take in spoons and forks. Those loops should again be made in different sizes, to suit from salt-spoons to tea-spoons through dessert size to dinner spoons and forks, the stems of which may be reckoned alike. Small articles must not be immersed in close bunches as in gilding, because the operation of silvering is much slower, and it is difficult to give motion to them so often. They should be strung upon a wire—a thin one, apart, and if possible between two anodes. Various arrangements are in use called "slings," "loops," "sockets," and "swivels," and no difficulty is usually experienced in the operation of wiring in silvering solutions (Fig. 6). For nickel-ing the wiring is the same as for silvering.

Fig. 6 Sling-Loop.

Wiring for copper deposition is in great part described in the section upon electrotyping. For ordinary plating with copper, the "slings" and "loops" need not be coated with gutta-percha, because the metal is not so valuable, but the slings may become too stout in time with deposited copper.

Motion in Solutions.—In gilding, silvering, and coppering solutions, having the articles in solution

is 'a' very great advantage. A very slight motion
will suffice, and it is best to have it up and down,
or parallel to the anode face, across the vat.   In
establishments with steam power the vats are
usually fitted with a frame, carrying the rods from
which to suspend articles.   This frame is upon four
wheels, moving for a short space upon rails fixed
upon the vat edges, and motion is given from an
eccentric upon the shaft.   But a simpler plan is to
make use of a roasting-jack, which may be employed
if the articles are between two anodes, or even
opposite to one another.   A frame, hung upon cords
and moved by mechanical means, is also in use, as
are heavy pendulums and other obviously appli-
cable pieces of apparatus.   Motion at intervals may
be given by the hand.

Positions in the Solutions.—Horizontally *under* the
anode surface is the scientifically correct position
for articles being plated.   This would hold good
could we procure and work anodes and solutions
perfectly pure, but the common impurities of all the
metals and solutions, accidental or intrinsic, prevent
any such position from being applicable in practice.
If we arrange a flat surface to be deposited upon
horizontally below the surface of the liquid, and
also arrange the anode horizontally over it, a few
inches off, the deposition will go on very steadily,
but on examination the deposit will be found rough,
dirty, and mixed with large spots of impurities
fallen from the anode.   All metals are alike, except,
perhaps, pure gold ; and in gold-plating the work is

done so fast that the positions indicated would not
do in practice, while the work must be examined
now and again.

A good plan, however, is to plunge the articles
deeper in the solution than the anodes, and the
plates may be inclined ; but, speaking plainly, and
as a worker looks at the question, it is a case where
" the game is not worth the candle." Even although
the scientifically correct method could be employed,
which is doubtful, supposing the non-existence of
impurities, only a very little less battery power
would be needed, and although the deposit would
be, perhaps, mathematically correct in thickness all
over the surface, very little would be gained, and it
is fairly clear that any advantage would be more
than outweighed by the loss of time in securing it.

Suppose, for example, that there is only one
anode, and that both sides of the article—a salver
—are to be equally plated, it is clear that the plate
must be turned occasionally in the course of silver-
ing, otherwise the deposit must be uneven—more
upon one side than upon the other. *The metal
always goes fastest upon that point or side next or
nearest to the anode.* Therefore, knowing this, an
intelligent plater will so arrange his anode surface
that the work may be done equally upon all parts
of the article. Anodes may sometimes have to be
bent—convex to suit a concave article, and con-
cave to suit a convex one. This is especially so in
electrotyping, where all shapes of anodes must be
used upon uneven surfaces to secure uniformity of

deposition. Large anodes, bulks of liquid, and currents deposit more evenly than small ones, where more care is necessary to produce good work.

Faults and Failures.—The operator should always learn first to deposit copper properly, because the metal is easily worked, and because it is cheap enough, and affords a guide to the best methods in dealing with silver, nickel, and gold. Dirt is, after all, the chief cause of failure. It is a comparatively easy matter to deposit a metal simply, but to lay it in molecular contact is quite another.

There is such a thing as *bad quality* of deposit, and the directions that are here given aim at placing in the operator's hands such rules as may prevent the deposition of *brittle* or *porous* metals. With regard to brittleness it may be remarked that, as a general rule, the result of battery power inadequate to the work doing is a brittle deposit, accompanied, in the case of silver and nickel, by a peculiar brightness of surface, and in gold work by a very pale yellow. Too much current, on the other hand, will usually produce a porous deposit, and if the current is very much too great, the metal may be thrown down in grains.

Scratch-brushing is to be resorted to in the best coppering, silvering, and gilding after the first coat is laid. This tests its adherent qualities, and reveals defects otherwise scarcely discoverable. It is only true economy of time and material to at once proceed to strip and re-prepare an article upon which the first coating is bad. It is seldom

that gôod gold work of silvering can be done without at least one scratch-brushing and rewashing after the *first* film is on, and before the main deposit· is laid. The same processs is resorted to if thè ·work in electro-coppering is to be well done. Care is necessary that the metal may go upon all parts of the surface with the same thickness. Any irregularity of this kind cannot be detected by weighing, but it may be quite prevented by care in arranging the anode surface to the work being done.

.Although the text-books speak of the exact equivalent of metal being practicable in electrodeposition, it is nevertheless almost an impossibility in batteries to dissolve a pound of zinc and get a pound of copper in the vessel. Trials for absolute work in this way will fail, because the zinc is never pure, and the arrangements are imperfect. To work scientifically in the art is scarcely in the power of every plater, although a knowledge of the subject of electrolysis would prevent a great many failures.

Preparing " *Old Work.*"—Old work is plate which is very much worn, exposing the real surface largely. To make a satisfactory finish on such work without completely removing the old plating is impossible. A great deal of such old plate is scoured clear with the scratch-brush and rottenstone, the " scratchings " being kept for subsequent reduction and recovery of the metal; but as a rule it is both quicker and cleaner to remove old metal by acids and other means. Scratch-brushing is

only applicable to smooth surfaces, cut work being defaced by having its edges removed.

To remove Silver from Copper, Brass, and German-Silver.— Prepare a sufficient volume of strong sulphuric acid to cover the article, stir in a little nitrate of potash (half an ounce to the quart of acid), and heat. Immerse the article, and if the action becomes weak before the silver is removed, apply more heat and saltpetre. Copper works best in this mixture, and it ought not to be exposed to the acid longer than is necessary.

To remove Gold from Silver it is usual to heat to redness, and to then throw into dilute sulphuric acid, when the gold will peel or fall off easily.

To remove Copper from Silver.—Immerse the article in a hot solution of perchloride of iron, to make which dissolve jewellers' rouge in warm hydrochloric acid to saturation; or simply immerse for a sufficient time in boiling dilute hydrochloric acid. Perhaps the best way to remove copper from silver and gold is to make the article the anode in a sulphate of copper solution.

To remove Tin and Lead from silver or gold, employ the hot solution of perchloride of iron, which will also dissolve copper.

Recovery from such solutions is generally effected by evaporating to dryness and fusing the deposit with soda (for gold). It is best to dilute silver solutions, and to precipitate the metal by stirring in hydrochloric acid.

Some platers practise the replating of old work

without taking off all the old coating, but the work is poorly done. It is often required to plate evenly over *soldered seams*. To prepare such seams, tie a pair of thin wires to a camel-hair pencil; let their ends dip down and follow the hair at a short distance over the work; the brush should be dipped in strong solution of copper sulphate. Copper will be deposited upon the seam, or if the solder contains much tin, it will plate by simple immersion.

Chemicals and Materials.

(*Alphabetically Arranged.*)

Accidents.—Cyanide of potassium is a *deadly poison*. If any of its solutions or any of the cyanide plating liquids are swallowed, there is little hope of recovery for the sufferer; death usually follows immediately, especially if the mixture is a strong one. For cyanide of potassium, or any of its solutions or mixtures, give a dilute solution of acetate of iron in large draughts, and allow the coldest procurable water to pour upon the head and spine. For any of the ordinary acids swallowed, the sufferer should be given tepid water, to induce vomiting, and for the same reason the throat should be irritated within with a feather. Milk, chalk and water, and the whites of eggs are also useful in such cases. If any of the powerful alkalies have been swallowed, such as soda or potash, give vinegar, the juice of lemons, or *very* dilute sulphuric acid (1 to 100). The greatest care should be taken in plating factories. It is noteworthy that very

few serious accidents are on record, although a
vast quantity of plate is turned out daily. The
naked hands should not by any pretence be put
into cyanide liquids, because the skin absorbs the
poison. If there is a break on the skin, this is
especially to be observed. A pair of long tongs
should be at hand for recovering articles that have
fallen to the bottom of the vat.

Carbonate of Sodium.—This substance is the com-
mon washing soda in every-day use. It should be
kept in a closed vessel, because on exposure to the
air the crystals lose their water and fall to a white,
powder.

Carbonate of Potassium.—A very common sub-
stance, and often used. It is also called "pearl-
ash." To be kept in closed vessels. 10d. per lb.

Caustic Lime.—This is the common "lime," or
"stone lime." It should be kept in closed vessels
in a dry place, as it is apt to absorb moisture and
swell. A good quality is of a clear white colour,
turning creamy on mixture with water. The hands
must not be put into the slacked lime.

Cyanide of Potassium.—A most important sub-
stance, and used in large quantities in making up
the chief solutions, and in numerous other opera-
tions. I shall, therefore, speak of it at some length.

The most important particular to become ac-
quainted with is that its quality varies to a wonder-
ful extent. The common varieties contain only a
small percentage of the actual cyanide, the rest
being salt of potash, quite foreign to pure cyanide .

ot potassium. The poorest quality is known in the trade as " black" cyanide ; it is pure rubbish, and should not be used in any process whatever. Then comes the usual white cyanide. The quality of this substance varies *from fifteen to ninety-eight per cent.* of the pure cyanide. It is not uncommon for chemists to call their cyanide "pure," when it scarcely contains 50 per cent. of the article in question. The price is no criterion of its quality, because cyanide of 50 per cent. is sold at prices ranging from 2s. to 8s. per lb., and sometimes the material is procurable as good as 96 per cent. at 5s. per lb. The salt crystallized costs much more ; but crystallized cyanide of potassium has no special advantage over the usual cake or stick varieties.

On account of the variable quality, cyanide of potassium should always be *tested* before purchasing in quantity. To test a sample, the method recommended by Glassford and Napier is very useful :— Prepare two solutions, one of cyanide and the other of nitrate of silver. Dissolve 1 oz. of cyanide so as to measure in a graduated vessel 6 oz. Dissolve 175 grains of the pure silver nitrate in 2½ oz. of water. Stir the cyanide solution slowly into the silver one until a precipitate is thrown down and then redissolved. The amount of the sample required to do this will at once show its quality, for it takes just 130 grains of pure cyanide to produce the effect. From the quantity used it is easy to calculate the quality of the cyanide. There is no better test than this when the water is distilled

and pure, and the nitrate of silver the pure crystallized variety. Never purchase cyanide of potassium of a lower quality than 50 per cent. Solutions made from poorer salts are not to be recommended. Throughout this little work the salt is often spoken of, and the impracticability of giving exact figures as to its quantity pointed out : most of the directions, however, indicate the quality as nothing under 50 per cent. If it is better less may be added ; if poorer, more—but so much the worse for the solution.

It is but fair to mention that I experience much difficulty in obtaining in any quantity, at a reasonable figure, a cyanide of 96 per cent. purity in Paris or London, and that I have had no difficulty in obtaining almost quite pure (98 per cent.) cyanide from the firm of Mawson and Swan, manufacturing chemists, Newcastle-on-Tyne, at 7s. per lb. To produce such a quality requires the exercise of the best skill, experience, and attention. The very best cyanide procurable is "*pure black cyanide*" (not the rubbish spoken of before). It is not easily obtained, and care must be taken to mention its purity, with the particular that the black colour is imparted by an admixture of carbon in the manufacture. Cyanide of potassium is also called prussiate of potash. It is easily made, and I therefore give particulars for this purpose. ·

The common ingredients are ferro-cyanide of potassium ("yellow prussiate of potash") and carbonate of potash. Crush the ferro-cyanide, and expose it to heat upon an iron plate until it is dried,

and a white powder is the result. Take also car-
bonate of potash and dry similarly. Weigh out
eight parts of the ferro-cyanide and three of the
carbonate, mix, and add one-and-a-half parts of
·powdered charcoal. Bring a clean iron pot or
crucible to a red heat, and slowly put in the
materials until they are all fused perfectly to-
gether. Stir with a rod of iron, and keep the pot
covered as much as possible during the twenty
minutes required for fusing properly. As soon as
all gas appears to have been given off by the liquid
m ss, take the pot off, allow to stand a minute, and
pour its contents slowly upon a plate of iron or a
slab of stone. Break up when cold, and bottle at
once.

Hydrochloric Acid.—This is the common " spirit
of salt " or " muriatic acid." It is easily obtained
nearly quite pure. It should be clear, unless the
colour arises from dissolved dust. Its price is
usually about 1d. per lb. The specific gravity of a
good kind will be 1·16. It may be had of extremest
purity at 1s. per lb.

Hydrocyanic Acid.—This is water in which is
dissolved a certain amount of hydrocyanic acid
gas. It is usually very weak. "Scheele's" is the
strongest, and contains as much as 6 per cent. It
must be kept in an opaque bottle. The gas is also
called "prussic acid," and is well known in medicine
under that name. Care must be taken never to
inhale it, whether arising from the liquid, or from
vats of liquid being evaporated. It is usually

better to make use of good cyanide of potássium
in stróng solution.

Mercury.—Much of the common mercury contains
lead.   Obtain of good quality, and if it is sus-
pected, keep it in a bottle for an hour or two, with
occasional shaking and dilute nitric acid over
it.   Bad mercury does a great deal of harm in
batteries.   There should be no drossy appearance
in a vessel containing mercury.   It may be cleansed
of superficial impurities by passing through wash-
leather.   Its price varies exceedingly.   It is also
called "quicksilver."

Moulding Materials.—(See *Deposition of Copper.*)

Nitric Acid.—This is the "aquafortis" of com-
merce.   It is somewhat difficult to obtain it quite
pure.   For dissolving silver it should be colourless,
and have a specific gravity of 1·420.   For Bun-
sen's cells it should be strong.   Its price in small
quantities is about 1s. per pound; in Winchester
quarts, at 25 per cent. less.

Sulphuretted Hydrogen.—This gas is prepared by
placing some sulphide of iron ("sulphuret of iron")
with diluted sulphuric acid in a flask.   The gas
comes off, and should be washed by passing through
water.   A small quantity of water should be used,
and if a solution of the gas is required it is obtained
by again passing into water.

Sulphuric Acid.—This is in constant requisition
by the electro-plater.   It is also called "oil of
vitriol."   It is, when pure, much heavier than water,
having a specific gravity of 1·84, and an oily ap-

pearance. It should be clean, because, although bad colour *may* simply be dissolved straw or other matter of no consequence, the acid may be of poor quality. To test for arsenic, pass through it a stream of sulphuretted hydrogen, when a yellow precipitate will indicate the presence of arsenic. "Dilute sulphuric acid" usually means acidulated water only—that is, one part acid to twenty of water. Stronger mixtures than this are particularised as to quantity. Its price is about 1s. per pound, pure, in small quantities, and in Winchester quarts 25 per cent. less. The commercial acid, in carboys, can be had at ½d. per pound, or 1d. in smaller quantities.

Syphons.—These are usually made from a piece of lead piping. They may also be of gutta-percha or glass. Before use, they should be filled with the liquid to be drawn off, the ends closed with the fingers, and the shortest end plunged in the liquid.

Thermometers.—Those with japanned tin scale, made for baths, are very useful. Their price is about 1s. 6d. The "Milk scale" ones are better when it is required to have the instrument permanently in the vat. Their price is about 3s. 6d. Those graduated on the stem are higher in price —5s.

Twaddel's Hydrometers.—These are very useful; their price is from 1s. 6d. to 2s. 6d. They should be in a set of three, and suitable for testing the specific gravity of light liquids, such as aqueous ammonia, and heavy liquids, such as sulphuric acid.

Besides these there should be at hand a supply of *test papers*—neutral tint litmus, or red and blue litmus. Filtering papers: these are discs of paper, put up in hundreds and of different sizes. They are used in funnels by doubling them twice at right angles, opening one of the folds and placing on the funnel. This is usually too slow for the filtering of large bulks of liquids. Larger ones may be made of good close calico, fastened on a ring of wood or iron. To filter alkalies or strong acids plugs of asbestos are usually employed to stop the necks of funnels. A *Galvanometer* is very useful, especially those with two circuits, for strong and feeble currents.

' *Purchase of Articles and Chemicals.*—Never purchase such things as earthenware wash-pots of instrument dealers if they can be had from the makers. (See the "London Directory.") Do not purchase batteries if they can be made properly at home. Always deal with some well-established house for chemicals, and unless you know good and bad, leave the qualities to your dealer—except in the case of potassium cyanide. Buy valuable metals from the refiners, and do not use gold coins. Purchase, acids especially, in large quantities at a time, and thus save money. It will be found best to purchase the distilled water required, but it will seldom be used if there is a supply of filtered rain-water. Compare prices before paying away money, and compare goods before buying in any quantity.

CHAPTER III

Batteries.

Electric Generators for Amateurs.—I devote a portion of my space to descriptions of galvanic generators specially suited to the wants of amateur electrotypists and platers. It is not without a certain conviction that such information is much sought for, and put to use when obtained, that I approach the matter at all. The difference between the price of batteries purchased and the cost of those made by the amateur is a sufficient inducement, apart from the knowledge so obtained, to construct these at home. Very few tools and little skill are required for the work.

For Nickel Plating employ the Bunsen cell, with instructions given under *Workshop Batteries.*

For Silver Plating one Bunsen cell will usually be enough, except where the need for a high tension current is indicated. (See *Deposition of Silver.*)

For Gilding.—A cell composed of a plate of carbon and another of zinc, clamped to a crosspiece of wood and dipped in a solution of bichromate of potash, acidulated slightly with sulphuric acid, will do very well for gilding. If the work

takes over a few minutes to do, the plates should
be moved up and down in the liquid to give it some
circulation. The same pair of plates will serve if
dipped in a solution of sal-ammoniac, or if the
articles are very small, in common salt solution.
No binding screws are necessary. The wires may
be soldered to the zinc and twisted in a hole
through the carbon plate. The whole may be
put together in a few minutes. Carbon (graphite)
is procurable free at the gas works. It is difficult
to cut, and it is generally cheaper to purchase it .
ready cut. The zinc may be thick roofing metal,
and if used in acid solutions should be amalga-
mated by contact with mercury after dipping in the
solution. If attention is given to moving the pair
in the liquid occasionally, gilding may be done
with a plate of copper and one of amalgamated
zinc in a weak mixture of sulphuric acid and water
(Fig. 1, p. 4).

I have gilded *without the use of any special battery*,
by employing the earth current generated by the
gas and water-pipes of a house. In damp places
this may often be done, simply calling the gas and
water-pipes the "poles" of the galvanic cell. It
will, of course, be necessary to find the direction in
which the current moves. It may very readily be
ascertained by plunging two plates of copper, con-
nected by wires with gas and water-pipes or fit-
tings, in a solution of copper sulphate. This kind
of natural battery is, of course, only an interesting
fact. It would not be honest to use electricity due

to the inevitable decay of the pipes.   Moreover,
such a current can only be obtained under special
conditions.

For experimental work such cells as are.already
described will prove useful to the beginner.   The
plates of a simple cell should have a surface fully
as large as that to be deposited upon.   Their shape
is a matter of no consequence.   It is only necessary
to mount them in a bar of wood, by their upper
ends, as near to each other as practicable, without
the chance of their touching each other.   The wires
should be covered with cotton or gutta-percha, or
should be kept well apart.

For Coppering and Electrotyping Experiments,
nothing is better than a pair of Daniell cells of
simple construction.   Pound jam-pots make useful
and cheap outer jars.   Within this is placed one of
porous earthenware.   (See *Porous Cells.*)   The outer
jar contains a strong solution of the sulphate of
copper in water, and the porous pot very dilute
sulphuric acid (ten to one).   In the outer jar place
a roll of sheet copper, and in the porous cell a
slip or rod of amalgamated zinc.   Solder the
wire to the zinc, or cast the zinc around it.   Sol-
der also the copper wire, or at least twist it in
a clean hole through the sheet.   This cell, so
charged, will work without alteration for nearly
a week.   To join the cells, fix the zinc wire
of one to the copper of the other, and take
the remaining wires to the depositing vessel.   If
one cell of double the size is wanted, join both

., coppers to one wire, and both zincs 'to the other.

When a powerful current of short duration is required, make a solution of bichromate of potash, and strongly acidulate with sulphuric acid—three ounces to the pint. In this plunge the zinc-carbon cell. The current may be kept up for some time by moving the plates up and down at intervals of one minute.

Workshop Batteries.

Doubtless the best galvanic generator for ordinary use in the plating-room is a large Smee or Daniell. The Smee is the most easily managed of any. (See *Frontispiece*.)

Smee Cell. For Coppering, Silvering, Electrotyping, and all purposes requiring a good current of large volume.—The containing trough should be of oak, well jointed, and coated with lead or asphalt. Its size will depend upon the work to be done. For a vat to contain as much as 100 gallons of solution to be worked with six anodes and depositing bars, the battery trough should be about three feet long, by one foot deep, and the same wide. The solution is simply acidulated water, about one to twenty, which may be renewed every week, or oftener, if required. At such times it should be drawn off with a piece of lead pipe, bent into the form of a syphon. The electrical arrangement consists of alternate plates of zinc and silver, or

zinc and carbon. Silver is the best, and may in the
end be as cheap as carbon. (See *Carbon,* p. 57.). The
silver is platinised (see *Platinum*), and each plate .
costs about 15s. They may be very thin. Six
plates, that is, three zincs and three silvers, should
be used. To preserve the silver plates, their edges
and bottom should have a strip of lead doubled
over them and hammered flat; this lead should be
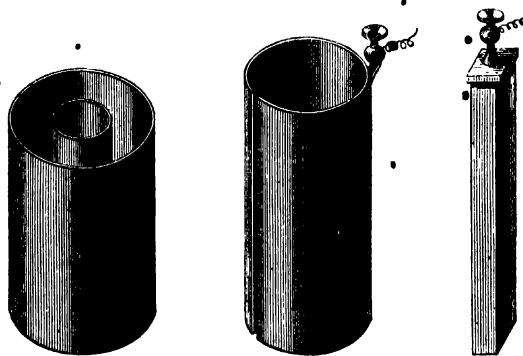
Fig. 7.—Daniell or Bunsen "Battery" Dissected.

well varnished. The zinc plates should be amalga-
mated. (See *Amalgamation,* p. 56.) They may be
mounted in any convenient way: a series of cuts or
slots may be made in a wooden cover for the cell, and
the plates put down through them. The plate tops
should be fitted with projecting wood bars to pre-
vent their falling through. Very stout wire should
be used to connect the plates. All the silvers may
be connected together by soldered wires, but it is

much better to have upon each plate top a common
binding screw, so that the whole may be taken
apart when required : a wire may then connect the
binding posts.   The zincs should be treated
similarly, when a wire from each combination will
form the two conductors—silver wire going to the
anode, and zinc conductor to the article being
plated.   A stout cord should hook into the battery
cover, go over a pulley, and have a weight on its
other end, by which the plates may be conveniently
lifted out of the trough altogether when not in
action, and partly when a less current is required.
In this way the current may be regulated with the
greatest nicety (Fig. 9).

Copper and Zinc batteries have been used ex-
tensively, but they are wretched generators, and
wasteful in the extreme; this is the old Wollaston
form, and is now out of use.   Platinised silver will
last for many years, and then may be sold for old
silver, so that the cost of a good Smee, although
more at first, comes to less than that of the
Wollaston in a short time.

Bunsen Cell.—This, next to the dynamo-electric
machine, is the best source of strong, steady
currents.   It consists of an earthenware jar, hold-
ing about half a gallon (for large currents), inside
of which stands a cell, of the same height, and
narrow, of porous earthenware.   These are the two
containing vessels : the outer one contains sulphuric
acid much diluted, and the inner one strong nitric
acid.   The "metals" used are, for the outer pot, a

roll or cylinder of amalgamated zinc, and for the inner one a block of gas-carbon. A wire from the carbon and another from the zinc form the con-ductors as usual. This battery is seldom used for silver, gold, copper, or nickel deposition, and when plating, such as brassing, is carried on which necessitates the use of large or strong currents, the dynamo-electric machine ought to be used, as it is
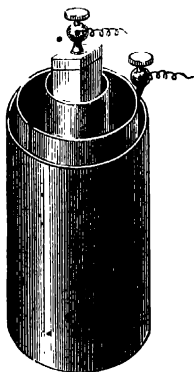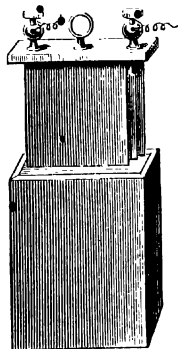

Fig. 8.—Bunsen Cell.   Fig. 9.—Smee Cell—Plates drawn up.

much less expensive, even with a special engine to drive it. The action of Bunsen's cell goes on, when strongly charged, with great vigour for four or five hours, and weaker after. The nitric acid gives off bad fumes, so that the cells should be placed out of doors, or on a window-ledge. To join the wire to carbon is no easy matter, as the carbon is porous, and allows the acid to rise in it, to destroy any

connection made. A heading of lead may be moulded upon it, and this may then be well soaked in hot melted paraffin, the wire being soldered to the lead. A brass clamp, with contact parts plated with platinum, makes a fairly good connection, but the best possible heading is spoken of under *Carbons*. These remarks apply to all carbons, although those used in Bunsen cells are more liable than the others to bad contact. (See Figs. 7 and 8.)

Grove's Battery is sometimes employed in electro-plating. Its construction is similar to the Bunsen, the only difference being the substitution of platinum foil for carbon. The acids are the same, and the time in action at full force about four hours. To save expense the platinum foil is sometimes too thin, and is very troublesome. The only real advantage in the Grove cell is the flat shape of porous cell often used. This renders the space occupied very small; but the whole arrangement cannot be recommended, and it is time that its use was a thing of the past in practical electro-metallurgy.

Daniell's Battery has been much used, but it gives rather too much trouble for rough work, such as brassing or even silvering. It is well fitted for *continuous* gilding; for example, for the gilding of wires, drawn regularly through the solution. It is also very serviceable in shops where a great deal of gilding is done, and for slow and fine electro-typing. The containing-pots are the same as those for Bunsen and Grove cells—an outer and a

porous cell. The liquids are solution of copper sulphate in the outer cell, and acidulated water in the porous pot. Copper is placed in the outer pot, a roll of the sheet being used, and zinc, in the form of a rod or cylinder, occupies the porous cell (Fig. 8). It would appear to be necessary for me to here warn the plater against a form of the cell recommended in the text-books. It is simply the old plan of making the copper cylinder into a complete pot, and dispensing with the outer containing cell. Such an arrangement is very common, and troublesome also, because the bottom joint usually leaks after a little use; and the first cost is greater than that of the porcelain cell. The construction may be varied to almost any extent, so long as a porous partition divides the two liquids. In action the cell is very steady, furnishing a good current at a constant strength for days together. If the acidulated water is weak the cell may work regularly for weeks together. Owing to this constancy, the Daniell is well fitted for all purposes where a very strong current is not needed. In practice the containing cells should be earthenware jars holding about a gallon ; the copper cylinders rolls of clean sheet, with a binding screw soldered on to each; the porous cells should be large, and the same height as the outer pots ; the zincs should be thick rods of the smoothly cast metal, and well amalgamated, and with a binding screw soldered to the top. Four of such cells will be found strong enough for almost all silvering operations employing

anodes twelve inches square. If the plater is experienced in his art, he will always use the Daniell in gilding if there is much of it to produce.

. *Fuller's Battery.*—This excellent generator of electricity, lately introduced, is well fitted also for gilding, and it gives even less trouble than the Daniell, while its strength is greater. It is not, however, suited to the plating of large surfaces. The containing-cells are the same as before. The zinc is in the form of a rod, flattened out at the lower end, and coated with sealing-wax varnish except at this end. A layer of mercury covers the lower end at the porous cell bottom, and the cell is then filled up with water only. The outer cell contains only a carbon plate, with a solution of potash bichromate strongly mixed with sulphuric acid— one to eight. The circuit should be closed after setting up for about six hours, when the action will be much stronger than at first.

Amalgamation of Zinc Plates.—This simply means the coating of zinc with mercury, to protect the naked surface from what is called "local action." This wasteful action is simply the result of hard or soft, good or bad, spots in the zinc, and the waste is caused by little *local* currents being set up between them. A surface of mercury connects all those objectionable spots together, and prevents local currents from forming.   '

It is only necessary to dip the zinc in its solution until its surface is clean, and then to rub the mercury on from a soup-plate, with a pad of cotton

wool or rag. Rub until a perfect surface is obtained,
dip the plate in water, and set up to drain. There
is much more trouble with cast than with rolled.
zinc, therefore care should be taken to cast rods in
a smooth casing, such as a roll of oiled 'copper
sheet, or 'an oiled *taper* brass tube. Sand should
never be used to produce good zinc. The neces-
sity for *re-amalgamating* is indicated when the sur-
face shows black patches which will not rub off.

Zinc for batteries should be of good quality.
Much of that sold is very impure. Rolled sheet
should always be used, because the surface is good,
and a tough zinc gives more force than cast plates ;
besides, it is almost impossible to properly amal-
gamate the latter. Its thickness should be nearly
¼ of an inch, and its price should not exceed four-
pence per pound. To bend into cylinders, it is
only necessary to warm or heat the sheet, when it
is easily curved. To easily cut, scratch deeply
with a steel point, run mercury therein, repeat on
the opposite side, and bend. Belgian zinc is
generally supposed to be the best for batteries. If
the new sheet is greasy, dip in caustic potash solu-
tion before proceeding to amalgamate.

Carbons for Batteries.—This substance is the
graphite of the gas retorts. It is not coke. It is
easily procurable in lump at any price, but costs
much more when cut into plates, as its working,
when the material is good, is exceedingly difficult.
It is generally cut with a thin strip of iron and
watered silver sand. Blocks for the Bunsen cost

less because they are more easily produced. Blocks
may be had at tenpence per foot long, but plates
cost much more, dependent upon their breadth.
Rods for Bunsen cells should be a few inches
longer than the pots, to protect the top contact
from the acid. A good carbon is of a clear grey
appearance, has a finely granulated surface, and is
very hard. They will last any length of time.

Connection with the top for the wire is a more
difficult thing to obtain than would be imagined,
especially with Bunsen carbons. The best possible
plan is to electrotype a head of copper upon them
in a sulphate of copper bath. Proceed as follows :—
With a hot iron spread a quantity of solid paraffin
upon the rod from the point the liquid reaches to,
upwards to within half an inch of the top. See that
the paraffin penetrates the substance. Then cut
a few notches in the unparaffined head, drill a hole
right through, and fasten a wire to project a little
at each side. Tie a wire around the opposite end,
and immerse in the copper solution of the Daniell
cell, or treat the head in a proper vessel like any
ordinary work. When the copper is thick enough
to stand hard usage, remove the rod, and drill a
few holes right through the new head ; soak in
water, and dry well in a hot place. Tin the copper
at the top, and if required solder on the wire or
binding screw, and then well soak the whole head
in melted paraffin. This will make an almost per-
fect and permanent connection, which the acid
cannot affect. Cells that are only to be used for

short periods need not be treated in this way, because a fairly good connection may be made with the ordinary brass clamp. But where Bunsen cells are used for brassing, or such work, the carbons should always be so headed. It is necessary to keep Bunsen clamps very clean.

Binding Screws and Clamps.—These are turned blocks of brass, with a hole run through to hold the wire, and a screw to fasten it securely, and assist in making a connection. Clamps are brass castings fitted for clamping the heads of carbon rods, pairs of Smee plates, zincs, and other purposes. They are made in all shapes and sizes to suit the different purposes. The price of binding screws ranges from 3s. to 6s. per dozen. They also are to be had in all required sizes, fitted with screws for wood-work, or tails for soldering on to the plates. The usual wood binding screw is a wretched affair, the " screw " being merely metal-thread, and not wood-worm thread. The French have introduced a useful screw, having tails made from wood screws. These should be asked for, as the others are troublesome. They have also brought out a good many new and useful patterns of large screws and clamps. The contact holes of clamps and screws must be kept clean. A rimer or a small file will be found useful for this purpose. Contact parts of clamps must also be kept bright, as electricity will not pass through dirt. The soldering on of screws may be done with a copper bolt, resin, and soft solder; cr spirit of salt, saturated

with zinc, may be used instead of resin, which is
very troublesome. Emery-cloth should always be
at hand and *made use of* every morning, not only
for battery screws which may be dirty at contact
parts, but for vat-rods, hooks, and the numerous
necessary connections about a large vat and
battery. Wherever soldering may be done, instead
of simply connecting, it is wisdom to employ it—
well-soldered connections never give any trouble.

Containing Cells for Batteries.—A battery " ele-
ment " or cell being composed of a pair or more of
zinc and copper, carbon or silver plates, immersed
in a liquid, a vessel of some kind is required to hold
both the " element " and the liquid—this is the
containing, or outer pot. Stoneware is the best
material in use. Pots of any required size are
obtainable. They should be in shape like common
jam-pots, and have no taper. Glass, ebonite, and
gutta-percha are entirely out of place in a plating
factory for containing-pots.

Porous Cells for Batteries.—These are procurable
in all required sizes. The price is something like
a penny per inch in height. Wedgwood & Co. make
excellent cells. For the Bunsen cell the material
should be very porous, but not so much so as to
allow water to run off the sides when filled and
stood up for test. A dew should appear outside
in a few minutes if the pots are soft enough for the
Bunsen. Red material is better for soft cells than
white. For the Daniell cell the pots must be
harder, and of closer grain, and white earthenware

is the best suited. Porous cells after use should never be set aside to dry, as they will crack. They should be kept soaking in water until required. The best cells are glazed at the top, but they may be difficult of procural. Daniell cells are very apt to deposit copper upon their porous partitions; some of the nodules may be knocked off, and others had better be covered with a chip of soft gutta-percha. The tops of Daniell porous pots should be soaked in melted sealing-wax, or in hot melted paraffin, and it is wisdom to soak the bottom also.

Unglazed pots are to be had either round or flat. The round ones are, of course, the more useful. Cells for Grove batteries are usually made narrow and flat, to contain a little acid and a thin plate. The form is a matter of little consequence. Substitutes for porous cells may be tubes of brown paper, stopped at the bottom, or wooden pots; but they are unsuitable, except as experimental apparatus. Porous cells for all batteries except the Daniell will last for many years if care be taken of them. Porous earthenware partitions for trough batteries are also procurable cheaply. They are useful for making up Daniell cells in troughs coated with marine glue.

Comparative Strengths of Batteries.—A great deal of misconception exists amongst platers as to the value of the term *electro-motive force.* It is not my duty to here explain its meaning; but a word or two upon its significance in the workroom may be

acceptable. It means, then,' *power to overcome resist-ance.* ‣ Thus, we may have a *current of vast volume,* but its force might be so low that a few inches of liquid between the anode and article might by its resistance entirely render the volume of no practical use—that is, no metal would be deposited unless we reduced the distance between, or rendered the conduction of the solution better. Now a current of *very small* volume, but of higher pushing power or electro-motive force, might do a great deal of work when one of low force would be useless. It should be distinctly understood that the force, pure and simple, is *entirely independent of the size of cell ;* a small cell has just as great power to carry its modicum of current through a given resistance as a cell infinitely larger. I wish it to be understood that the word current is the expression used to indicate the amount of electricity given off, with no reference to its force or pushing power. *Strong current* of course means a good volume of electricity moving with much force—that is, electro-motive force and volume combined.

Speaking as I do to the worker himself, who cannot be expected to be a trained chemist or electrician, and give, as he does, his services for a small wage weekly, I am anxious to impress upon his understanding the importance of these remarks as bearing upon the practice laid‑ down in this work. He should understand that small volumes of liquid may be worked with large currents if the work is to be done quickly, but the currents must

have *force* to overcome the resistance presented by the small area of liquid. To understand that liquids and solutions present an *enormous resistance* to the passage of electricity when compared to metals, will greatly aid the plater to an intelligent conception of the laws of electricity and resistance, as applicable to the purposes of electro-metallurgy.

Rules to work by are, of course, given here also, but no specific directions can entirely grasp the whole needs of a practical plater. The electro-motive force, then, of the batteries spoken of is, comparatively, as follows :—

Cell.	Comparative force.
Grove's, with purest nitric acid in porous pot .	100
„ with nitric acid, specific gravity 1·33 .	98
Bunsen, with purest nitric acid	100
„ with acid of specific gravity 1·33 . .	99
Smee, dilute sulphuric acid 1 to 12 . . .	30
„ „ „ 1 to 20 . . .	24
Daniell, with dilute acid 1 to 10 . . .	50
„ „ „ 1 to 20 . . .	35
„ with half-saturated solution zinc sulphate	25
Fuller „ „ „ „ „	30

The statement of " force " must be accepted with much caution. Thus :—It does not necessarily follow that, although the force of a Daniell is tabulated as half that of the Grove, it is equal to half the work a Grove cell can do; two Daniells, or even four, are *not* equal in working power to one Grove cell, even although the surfaces are equal. This discrepancy is due to the high conductivity of the strong acids in the Grove, and to the low con-ductivity, or enormous resistance, offered by the

one to fifty instead of one to ten, the action may be prolonged for many days at a time. In this condition the cell may be used for silvering, or other work usually done by the large plating-room Smee. The Bunsen has also been used for gilding, but it is not economical of zinc to work in this way. In using the Bunsen with concentrated nitric acid, fumes are given off, which are very strong as the pots are being emptied : they must be avoided, as they are exceedingly unwholesome, nor should they be allowed to spread in a room where they can do harm. It will be useful to have two sets of porous cells for the Bunsen, so that one set can be soaking out the nitric acid in water, while the fresh ones are in use. All the brass parts, plates, and any connections of the Bunsen battery should be washed in water after pulling to pieces, and emery-cloth must be made good use of for the contact points.

To work the Daniell Battery.—This cell gives very little trouble when properly attended to. The amount of management required will depend in great degree upon the charge in the zinc compartment. If the cell is worked by strongly acidulated water, the attention required will be at a maximum, and in this " short period " condition, the battery cannot be expected to work without attention over seven days. If, on the other hand, gilding only has to be done, or a weak current only is required, we charge the zinc pot with *water only*. The result is that, after a few hours' work, zinc sulphate will be formed, which will serve in the water to work

the cell without any attention for months at a time; in this state the attention required is, at a minimum. So little attention as this will not serve the Smee battery, no matter how weak the acidulated water may be made. Hence the advantages of the Daniell in electro-gilding, or when a small current is required.

No sooner is the circuit of the Daniell closed, than the copper solution is decomposed into its constituent parts—copper and sulphuric acid. The metal is deposited upon the copper cylinder, and the sulphuric acid finds itself drawn into the porous cell, where it maintains the zinc solution in a constant condition. The whole cell is, in fact, nothing less than a depositing vessel, and it may be worthy of remark that the Daniell cell afforded the first opportunity for observing electro-deposition ; it was the *ab initio* of electro-metallurgy and all it has grown into. The copper is thus by deposition kept perfectly clean, and from accumulating a film of gas, which in many cells puts a stop to the action, and the zinc cell is constantly supplied with sulphuric acid. The chief trouble is the liability of the copper to find its way into the porous pot by that troublesome creeping action called endosmos. If copper is allowed to get into the porous pot, it will be deposited upon the zinc, act with that metal as a small *local cell*, and waste the zinc without adding to the outside circuit current. The tops of porous pots should for this reason be well steeped in hot melted paraffin, and as

the bottom is also very apt to accumulate nodules
of copper outside, it should be treated in the same
way. The copper solution should be strong, and
as soon as the liquid shows a pale colour, instead
of a deep blue, more copper sulphate should be
added. A great many methods exist by 'which the
copper solution is kept up, by crystals hung in it
and otherwise suspended. I simply consider this
an excuse for laziness, and it will result in the cell
being forgotten at times when it ought to have
attention. It works well enough for telegraph
batteries, but it is a much better plan for the plater
to throw in some crushed copper sulphate—a small
quantity—every few days, according to the work
doing. If the sulphate is crushed finely enough it
will melt before it reaches the bottom, and give no
trouble. As to the zinc cell, if it is worked by zinc
sulphate, as before suggested, no amalgamation of
the rod is required; but if the usual acidulated water
is employed, the amalgamation must be attended
to about every month or less. The solution, in the
first case, should be one *half* saturated with the
zinc salt, and when the mixture is seen to deposit
crystals about the zinc, half of it should be poured
out, and water added. A watch should be kept
upon the porous pot for nodules of copper. If they
can be knocked off, do so, and cover the spots, if
not quite free of copper, with soft gutta-percha or
marine glue, or even shellac varnish. Nodules will
grow with astonishing rapidity if they are not
covered or removed regularly. It is wise to have

two sets of porous pots for the Daniell—one set being left soaking out its salt while the other is working. Connections may be wires simply soldered on, but it is much better to have binding screws upon the metals.

To work the *Grove* cell, the directions given for the Bunsen will answer generally.

To work the *Fuller* cell, attend to the bichromate salt solution. When it shows pale, add more salt, and some sulphuric acid ; also give attention to the zinc sulphate solution, and treat otherwise as a Daniell—there will be no trouble with deposited copper, and the salt does not creep much.

Remarks upon Batteries.

For all real large work in the direction of coppering, electrotyping, silvering, and nickeling, it is necessary to use a source of large currents such as the large Smee battery, or better still, a dynamo machine as described at p. 74.

For gilding, or work requiring only a small current, use may be made of the Daniell in preference to the Smee or Fuller ; but the Smee will do the work well, and the Fuller will do for small work.

For brassing, depositing iron, and all work requiring a powerful current, make use of the Bunsen. (See also *Dynamo-Electric Machines.*)

Except for coppering alone, it is wise to have the Smee trough divided, by wood well pitched, in

the middle, so that two Smee cells may be at hand when required. Have, say, two silvers and two zincs in each cell, and when higher electro-motive force is required, join the silvers of one cell to the zincs of the next, and wires from the remaining zincs and silvers will give the force of two cells and the current of one only. In ordinary work, when high force is not required, and great volume is of more use, join all the zincs to one wire, and all the silvers to the other. These junction wires should be of copper, and stout, and should be insulated, covered with gutta-percha or tarred hemp.

Cost of Batteries.—A large pair of Smee cells, with plates a foot square, four plates in each compartment, and well made, can be purchased, or made to order, for less than £10. Or the same may be made in the plating-room, using large jars instead of a trough, not reckoning labour, for £5. Such batteries last for many years, but of course care must be taken to renew the zinc plates when worn.

The *Daniell.*—A pair of these cells, holding when empty about a gallon of liquid in the outer pot, should not cost more than £1 10s., and they may be made for half that sum, not reckoning labour. A pair will usually be enough.

The *Bunsen.*—Six of these should be at hand. A battery of this number of half-gallon Bunsens should not cost over £2 10s. It is not better to make than to buy these, because zinc and carbon are so hard to work without the proper tools.

The *Fuller.*—This being a very simple form of

cell, it will be better to make than to pay fancy prices for it.   A pair, of half-gallon size, will usually be enough.   For very large cells, it will be · best to mount three blocks of carbon around a circular cover of lead, instead of one plate only.

Regulating the Force and Current of Electricity.— The limits within which good work may be produced in silvering, coppering, and gilding are fortunately pretty far apart, but a great many of the solutions require careful regulation of the current to get a good deposit.   Throughout my remarks upon solutions are scattered directions as to the use of the power with which we are dealing, but they simply point to the fact that higher force is needed here, less force there, more volume, and so on.

To gain electro-motive force, or a *stronger* current, immerse the plates so that the surface of each plate will correspond to that of the anode, and *add* more cells, by joining their zincs to the already used carbons or silvers as the case may be—this is called adding in *series*, and each cell so added augments the force or power to drive a deposit over a surface, or to work through high resistance.

To gain *greater*, *larger*, or more *voluminous* current, use *more surface* in the battery.   That is, immerse the Smee plates farther, or if the battery is a Daniell or Bunsen, join other cells, copper to copper and zinc to zinc; or, which comes to the same thing, join all the coppers to one wire, and all the zincs to the other.   It is very seldom indeed

that the plater need be at fault. (See also *Dynamo-Electric Machines.*)

If the force from one cell is *too high*, which is a rare occurrence, interpose a few yards of fine copper or iron wire in the circuit.

The ordinary terms "*intensity*" and "*quantity*" of current have not been employed in this treatise, simply because the term intensity is not rightly applied, and leads to erroneous notions of electric force, and both terms would be somewhat puzzling to the every-day worker. I have preferred to employ the more accurate terms electro-motive force, current (or volume), and resistance. We are dealing with force (pressure), current (flow), and resistance to flow. These matters can be expressed in definite units, as explained farther on.

The Galvanometer.

Some platers, especially those with little or no scientific knowledge, who work by " rule of thumb," get through the best of work without any instrument for detecting the presence of electricity, or measuring its strength. It is not unusual in the plating-room to test the strength of the current by placing the wire ends on the tongue; others test by the spark which will pass between the ends on separating them, and by running one end upon a file to which the other is tied. These latter methods are of the most delusive kind possible, and will only be a rough guide with *one particular length of*

wire, for long wires give much longer and larger sparks than short ones.

The construction of a galvanometer is very simple, as an instrument for detecting currents, and to a certain extent indicating their strength, is only a suspended magnetized needle, having around it a few turns of insulated wire. The principle of the galvanometer—that a freely suspended magnetic needle tends to place itself at right angles to a current-bearing wire—is very generally known to platers.

Galvanometers should have two circuits—one of fine wire and a good number of turns for weak currents, and another of a few turns of stout wire, or one turn only, for very strong currents. With all such common galvanometers comparisons only can be made, and not absolute measurements of electricity. They are very useful for various purposes in the plating-room, especially in testing the strength of new cells; or, being placed in the circuit, indicating whether or not the battery gains or loses power during any plating or typing operation. The stout circuit is usually suitable as an indicator of the state of the current before commencing work every morning, or after cleaning out and refreshing the battery. Tests taken during the working and at other times will show when the solution of zinc sulphate is getting so strong as to weaken the current, and when it is time to renew the acidulated water. Good galvanometers, with two circuits and needle on agate centre over

graduated card can be procured at prices varying
from 10s. to £2. Now that both volt and ampere
meters are procurable, it is inexcusable to work with
currents at random, in ignorance of their strength.

Dynamo-Electric Machines.

The old-time voltaic battery is fast giving way
before the dynamo. The immense progress made
in the perfecting of dynamos for electric lighting
is having its effect upon the increasing industry of
electro-plating. Electricity derived from power is
in every way to be preferred before the current from
batteries. It is more economical. It is more de-
pendable, and not liable to failures or fluctuations.
The source is less troublesome and more cleanly.
Ample current and electromotive force are gene-
rally available when a dynamo is employed.

Many intelligent electro-platers are possessed of
dynamos and yet do not understand them. Be-
ginners in the art are also apt to neglect the study
of the production of dynamo electricity. But this
state of things need no longer exist. Ignorance of
the subject is now quite inexcusable. Excellent
text-books exist for the information of all en-
gineers. But in many cases these special works
teach more than the ordinary electro-plater need
know. A sketch of the main features of dynamo
working may be useful in these pages; but the
reader should beware of neglecting the study of
voltaic batteries in favour of dynamos. The voltaic

battery in itself exemplifies the salient facts of the art of electro-metalling. For instance, a Daniell battery is a copper-plating apparatus as well as a source of electricity. It is from the voltaic battery that most platers have taken their first lessons in the art of electro-metallurgy.

Nature of the Dynamo.—A dynamo is not strictly a source of electricity. It is properly a converter of mechanical energy into the energy of electricity. It returns to us a large percentage of the force used in driving it. The return is, however, in the form of electricity.

When a magnet is moved near to a closed circuit, such as a coil of insulated wire, currents will be *induced* in the circuit. When the magnet is moved towards the coil there will occur in it a direct current ; when the magnet is moved away there will occur an inverse current. The magnet may be stationary, while the coil is made to move. The result will be the same. If the coil be made to revolve rapidly, so as to change its position with respect to the magnet frequently, there will be induced in it rapidly alternating currents. To move the coil, energy must be expended. A dynamo machine consists of a large magnet and a more or less complex coil of wire called an armature. The magnet forming the magnetic field is known as the field magnet. The armature is usually the revolving portion. It moves around in close proximity to the field magnet. These are the two chief parts of all dynamos. The third part

consists of an arrangement called a commutator.
It is intended to commute alternating currents
into direct currents, and also serves to collect
the currents for use exterior to the dynamo. The
first machines of this kind were known as magneto-
electric machines. They were merely composed of
steel magnets and coils of wire, often encircling
soft iron cores. These magneto machines are not
now much used. Steel magnets have been dis-
carded in favour of electro magnets composed of
soft iron. The iron becomes powerfully magnetic
upon being surrounded by a coil carrying a current
of electricity. A dynamo may be regarded as a
machine in which such an electro magnet is used.
The soft iron always retains a trace of magnetism
after the current has been stopped. This trace
suffices to set up a feeble magnetic field. The
revolving armature has induced in it a feeble
current. This current, or a portion of it, passes,
however, at once through the coils of the field
magnet. The field thus becomes stronger. The
more powerful field induces still more energetic
currents in the armature, which further energises
the field, and so the action goes on until the machine
has attained its full strength of current. A very
slight force suffices to turn the armature at first.
But as the process of mutual strengthening goes
on, more and more energy is needed to turn the
armature.

The attributes of the dynamo are similar to those
of the voltaic battery. Every voltaic cell is capable

of exerting a certain electromotive force. Every additional cell joined in the same circuit adds its force to that of the first. The electromotive force of the battery is thus that of one cell multiplied by the number of cells composing it. This is well understood. Force may in this way be nicely regulated. It is not, however, so generally understood by platers that a dynamo is dependent upon much the same principle. Each turn of wire forming its armature evolves a certain electromotive force. The turns may be regarded as the component cells of a battery. The electromotive force of the dynamo will thus be that due to one turn of the wire multiplied by the number of turns composing the armature. The dynamo, however, evolves a lower or higher electromotive force as the rate of rotation of the armature is slow or fast.

Dynamos, as ordinarily built, evolve high electromotive force. Machines intended for electro-plating are specially designed to evolve low electromotive force. In an ordinary electric-light dynamo the armature is composed of a large number of turns of fine wire. In an electro-plater's machine the armature is composed of very few turns of a very thick conductor. Hence an electric-light dynamo may evolve a pressure of many hundred volts. The volt is the generally recognised unit of electromotive force, or *pressure*, as it is now commonly termed. This unit is about seven per cent. less than the pressure exerted by one cell of a Daniell battery. An electro-plater's dynamo is seldom

required to develop a pressure exceeding five such volts. To accomplish this the armature is made from thick conductors, forming few turns, and 'moving at a moderate speed.

The current, or rate of flow, evolved by a voltaic cell depends upon its size. In the same way the current evolved by the dynamo depends chiefly upon the sectional area of the conductors forming its armature. In both cases the current depends upon the resistance of the whole circuit. A large voltaic cell will evolve a large current in a circuit of low resistance. In the same way a dynamo having an armature of low resistance will evolve a large current of low pressure in a similar resistance. What is lost in electromotive force is in both cases gained in current.

Dynamo-electricity is now always measured and expressed in terms of the units. The volt signifies pressure, as before mentioned. The unit of current is known as the *ampere*. Its significance is easily understood if we bear in mind that a voltaic cell or dynamo giving a pressure of one volt will yield an ampere (one unit) of current in a circuit having a resistance not exceeding one ohm. This ohm is the unit of resistance. A column of mercury 106 metres in length and 1 square millimetre in section, at a temperature of melting ice, offers a resistance of one ohm.

Dynamos as now built are specified to be capable of exerting an electromotive force (pressure) of so many volts, and to yield a current of so many

amperes, at a certain given speed of rotation. This
system at once removes the old trouble--some ele-
ment of uncertainty regarding the performance of
dynamos. .

Typical Dynamo.—In Fig. 10 is depicted a com-
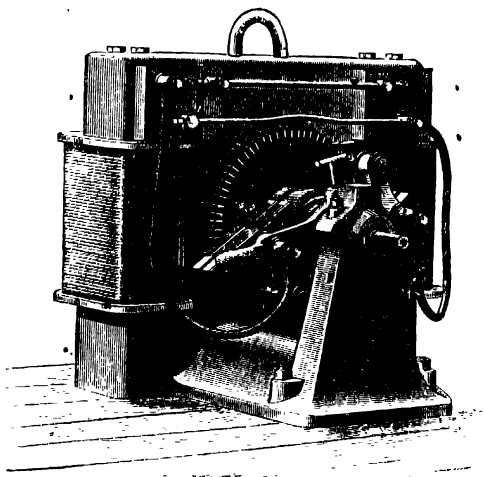plete dynamo of the "type industriel," having a

Fig. 10 —Sautter-Lemonnier Dynamo.

gramme ring armature wound with conductors of
low resistance. This armature is mounted on bear-
ings, so that it revolves between the poles of a
massive twin electro-magnet, forming the frame-
work of the machine.

Fig. 11 exhibits the armature removed from the

field magnet and bearings! It consists 'essentially of a'soft iron ring, overwound with several convolu- . tions of insulated copper strap. The extremities ' of these coils are connected to the plates by the commutator, or collector, shown mounted upon
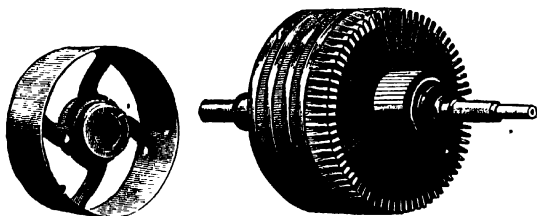
Fig. 11.—Complete Cylinder-Ring Armature.

the same shaft. The pulley, shown separate, is intended to receive the driving 'strap imparting motive power.

Fig. 12 represents the brush rocker. This ar- .
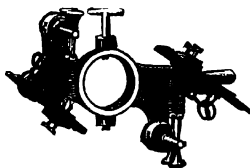
Fig. 12.—The Brush Rocker.

rangement is mounted upon the main 'casting axially with the shaft. It serves to hold the copper slips, or "brushes," that press upon the commu- tator, and receive the current therefrom. By setting the brush holder'to one side or the other of a certain

" line of best collection " upon the commutator, the power of the dynamo may be regulated at will to the work being done.

Fig. 13 depicts the field magnet and frame with the armature removed. The pole pieces, forming arcs, are of cast iron. The cores of the exciting
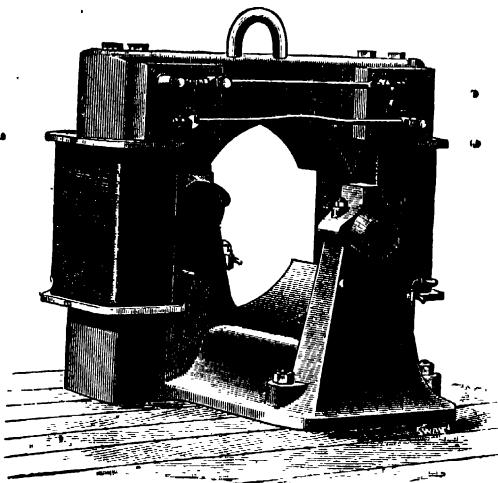
Fig. 13.—The Base, Bearings, and Field Magnet.

oils are of soft wrought iron. Fuller information oncerning the construction of these and other ynamos will be found in the author's treatise on *Dynamo Construction.* In Chapter IX., " Dynamo Iachine Working," will be found information bear-ng upon the employment of the dynamo in prac-cal plating.

CHAPTER IV.

Deposition of Copper.

Its Salts.—The most common salts of copper are the sulphate, acetate, nitrate, cyanide, chloride, protoxide, and suboxide.

Sulphate of Copper.—It is always better to purchase this than to attempt its production at home or in the plating factory. It may be obtained nearly pure at about 6d. per pound. A good test of its quality is in its appearance. The crystals should be as large as hazel-nuts, and of a clear deep blue colour. The poorer qualities always contain an admixture of *green* substances. These are iron, and samples showing it should be discarded. This salt is also commonly called "blue vitriol," "blue-stone," and "Roman vitriol."

Acetate of Copper.—This is very generally called "crystallized verdigris." The crystals are dark green. It is distinguished from common verdigris by its finer quality. Acetate of copper is more cheaply obtained by purchase than by making at home. It is somewhat expensive, as its price varies from 4s. to 6s. per pound, but a small

quantity is usually sufficient for the purposes of the electro-plater.

Nitrate of Copper.—It is usually made by dissolving clean copper sheet in nitric acid, afterwards evaporating the solution nearly to dryness by boiling and setting aside to crystallize. It may be obtained commercially, pure, at about 2s. per pound.

Cyanide of Copper.—This salt is much used. It should be made at home. To make it, prepare a solution of cyanide of potassium, four ounces; water, one quart. Prepare also a solution of like bulk, using, instead of cyanide, sulphate of copper. Pour the cyanide solution into the copper one, slowly and with stirring, just as long as a precipitate is thrown down. Pour off the liquid portion, and wash the powder, which is copper cyanide, by filtering with more water. The powder should be of a good green colour. Care is necessary to avoid the fumes of cyanogen given off during the precipitation, especially if the potassium cyanide be of fine quality.

Chloride of Copper.—" Aqua-regia"—one measure of nitric acid and two of hydrochloric acid—is employed to dissolve the copper, the solution being afterwards evaporated nearly to dryness and set aside to cool and crystallize. Commercial price, 5s. per pound.

Protoxide of Copper (Black).—The nitrate is usually employed to form this. It may readily be converted into the black oxide by heating to red-

ness in a covered crucible. The mass is set aside to cool, when it is washed and dried. Commercial price, 3s. per pound.

Suboxide of Copper (Red).—It is always better to purchase than to make this salt, as it is seldom used. Its price varies with that of copper, but it may be taken at about 6d. per ounce.

Simple Immersion Coppering.—This process is applicable to the coating of articles of iron or steel, so as to give them the appearance of being made of copper, or to protect them from rust. A solution of copper sulphate is made (saturated), and to this is added one-half its bulk of acidulated water. The articles must be cleaned well, and immersed for a minute until a coating is obtained, when they are taken out and well washed, and afterwards quickly dried by plunging in boiling water and steaming off, or placing in hot sawdust. If the articles do not get well coated in this solution, dilute it still further, and try again.

I have seen the coating of small iron articles carried on by shaking them about in sawdust well wetted with acidulated sulphate of copper solution. Another process, suited to the coating of cast-iron articles, is carried on with a solution composed of ten parts of nitric acid, ten of chloride of copper, and eighty of hydrochloric acid. The articles are immersed several times, and rubbed with a woollen cloth between each immersion. In the coating of iron wire, it is recommended that drawing the wire be resorted to so as to con-

solidate the coating and give it better adhe-
sion.

The simple-immersion process employed for the
coating of such large objects as statues and lamp-
posts is carried on in a solution composed of water,
five gallons; fifteen pounds of sodio-potassic tar-
trate; five of soda lime, and two of copper sulphate.
These substances are immersed in the water and
well stirred, and if there is any difficulty in dissolv-
ing them the water should be warmed or plenty of
time given. The articles should be immersed in
the liquid by means of zinc wires, or a piece of zinc
should be tied to and immersed with them. The
work is done slowly, and at least five hours are
required to effect a good coating of the metal. The
articles must be well washed in water after coating,
and dried.

Coppering by the Battery Process.—This is by far
the best method for copper-plating, as any required
thickness of copper can be laid upon the article
quickly. The connection between the real and
false surfaces is of a much more permanent and
satisfactory character.

A good coppering solution may be made by dis-
solving four pounds of crushed copper sulphate in
twenty pounds of water, adding, after the sulphate
has dissolved, one pound of sulphuric acid of good
quality. This solution should be filtered and kept
clean. It will not do for depositing upon zinc,
steel, or iron.

For deposition upon steel, iron, and zinc, a

cyanide of copper solution is required; throw down the cyanide with a solution of potassium cyanide, wash, collect, and dissolve in a solution of cyanide of potassium. A simple way to make the solution is to dissolve two pounds of cyanide of potassium (50 per cent.) in a gallon of water, add cyanide of copper as much as the liquid will dissolve, and then add free cyanide of potassium, of which about four ounces will suffice. When in use this solution should be heated, although it will work cold, but in the latter case the deposits will not be so smooth, or adhere so well, and more battery current will be required.

The first solution will be found suitable for all purposes of copper deposition upon moulds for *electrotyping*, or upon ordinary articles for plating them with copper. Articles to be coppered are cleaned in the usual way (see *Preparation*), and hung in the solution a few inches from the anode by means of a copper or brass wire. If the deposition goes on too fast, the coating will be of a dark colour, and the metal will not stand. This is generally caused by too strong a current, and may be remedied without altering the current by withdrawing the object from the anode, so as to interpose greater resistance to the current. 'If the work is done too slowly, the deposit will be of an exceedingly fine and crystalline nature, and very liable to crack. This is caused by too weak a current, or by the anode and article being too far apart. The remedy in either case is obvious.

Anodes for Copper-plating.—These are simply sheets of clean copper. They are connected to the copper pole of the battery, and are hung in the solution so as to enable the plater to expose more or less anode surface to the solution at will. If a galvanic cell be joined to a pair of copper sheets, one on each side of a vessel containing sulphate of copper solution, one of the sheets will begin slowly to dissolve, and the other to acquire a deposit of copper upon its surface. This will go on until all the copper of the anode will be thrown upon the receiving plate, while the solution remains' substantially the same—that is, its original copper is upon the plate, but a fresh supply has been obtained from the anode. This is the fundamental peculiarity of the plating process.

Working Copper Solutions.—The battery power should be two cells for general work, and where the resistance is very low, one cell may be employed, but greater satisfaction will be secured with two. Their plates should have an area at least equal to that of the anode or anodes employed. They must be of the constant kind, and Daniell's or Smee's will be found the most satisfactory cells in work. It is a good plan, where Daniell cells are employed, the plates of which acquire great deposits of copper, to use such plates for anodes, so that some immediate return for the expended copper may be secured. As in all other plating operations, a bar should be laid across the edges of the vessel containing the solution; this bar

should be connected to the zinc pole of the battery, and the articles to be deposited upon hung upon it into the solution. It is usual and handy to provide another bar, carrying the copper anode connected to the copper pole of the battery. This bar may be in two halves, held together by strong india-rubber bands, so that the anodes may be clipped by it and pushed into, or withdrawn from, the solution at will without any other arrangement. In this way one anode plate will usually be sufficient. But many other arrangements may be adopted suitable to special kinds of work, most of which are touched upon in my remarks upon *Vats* (p. 17).

Copper is very easily deposited, and it is upon this metal that I should recommend the would-be plater to serve his apprenticeship. It is cheap, and little loss can occur in its use. These remarks apply only, however, to the copper sulphate solution, cyanide solutions being more difficult of management. Care must be taken that the solution does not become too dense. This defect will be indicated by streaks upon the articles, and a thicker deposit upon the lower than upon the upper parts. Water should, in such cases, be added, and the solution stirred. It is wise to stir up the liquid every evening after stopping work. A little diluted sulphuric acid should be stirred in every evening if the anode does not look bright and clean. But care is necessary that too much free acid is not added, because in some cases the anode will be dissolved while the current is not passing; and when

the current is passing, the anode will be caused to
dissolve faster than is required to supply the metal
being deposited upon the article. This would
cause the solution to become very dense, and to
deposit unevenly, and in streaks. Impure anodes
are exceedingly troublesome, as they become black
with a kind of dirt which is usually insoluble in
the solution. The remedy is to employ either the
copper cylinders of the Daniell battery, or to em-
ploy a more expensive kind of copper sheet. With
care, by brushing and other treatment, the anodes
may be kept clean, but this rubbish, which consists
really of a wonderful variety of common and rare
metals, chiefly tin, collects at the bottom of the
vessel, and must not be disturbed, as it settles upon
the articles being plated, causing dirty work.

In working the solution of cyanide of copper in
cyanide of potassium, great care is necessary to
look after the amount of free cyanide. If there is
too much free cyanide, the anode will dissolve too
fast, and a great deal of dirt will fall to the bottom.
If there is too little, the anode fails to dissolve, and
the conductivity of the solution is impaired, so that
the current cannot do work, and is wasted upon
resistance. To obtain thick deposits from cyanide
solutions, greater care is necessary than in working
sulphate ones. There is a greater tendency to stop
depositing, owing to a dirty surface and other con-
ditions. The surface obtained from sulphate solu-
tions is exceedingly beautiful, but those deposited
by the cyanide liquids are usually very bad in

colour, and need extra scratch-brushing to bring
them up. When very thick deposits are required
upon iron or zinc, it will be found almost necessary
to first secure a very thin coat in a cyanide solution,
remove and wash *rapidly*, dipping at once in the
sulphate solution, from which any required thick-
ness may be secured.

Distance between Anodes and Articles.—This varies
greatly with the size of the objects, their shape,
and the current passing. Small surfaces or electro-
types upon which a rapid good deposit is required,
may be kept as near as possible to the anode—that
is, about one or two inches from it—if the surface
is flat, but if there are protruding parts and inden-
tations, the distance must be greater on account of
the tendency of the deposit to go on fastest upon
the nearest points. Much more equal deposits are
to be obtained when the distance is six inches than
could be secured at three inches, unless the surface
is really flat and parallel to the anode plate. To
a great extent the rapidity of deposition is depend-
ent upon the nature of the surface, and upon the
distance apart, because both these conditions affect
the strength of the current passing. The nearer
the article is to the anode the faster will the work
go on. But attention must be paid to 'the condi-
tion of the metal. If the work is done too quickly,
or with too strong a current, the metal cannot be
depended upon, and if it is done too slowly, or
with too little current, the metal will be crystal-
line. From the cyanide solution the deposit ob-

tained with ordinary battery power is of a dull
colour; but when the current is added to, the coat-
ing is nearly bright.

Time necessary in depositing Copper.—In sulphate
solutions there should be no difficulty, with a suit-
able current and the object and anode properly
arranged, in laying a thickness of one-eighth of an
inch in two days, and when the work is forced, with
the utmost applicable current, a good electrotype
should be obtained in ten or twelve hours—and
this of good tough copper. Copper-plating should
be done to a good thickness in one hour or less.

Electrotypes of Copper.—In the foregoing remarks
are given the necessary directions for depositing
the copper upon goods direct, securing a plating of
copper. Electrotypes, on the other hand, are *copies*
of objects in copper, and have, therefore, a separate
existence of their own. They are removable de-
posits. If an ordinary coin is deposited upon as
in simple plating, but with the precaution *not* to
chemically clean it so that the deposit may not
permanently adhere, the plating will go all over
it. If a thickness of writing-paper is allowed to go
on, it may be cut off, upon removal from the solu-
tion, with a knife. It will be observed that, as the
deposit is easily removable, it has upon its inner
face the finest possible lines and markings of the
original. It is, in fact, a *complete fac-simile*, in
reverse, of the coin's surface. The copper deposited
upon the Daniell cell cylinders will be found upon
removal to have taken an exceedingly faithful

copy of the surface upon which it has been thrown.

In these pages no notice has been taken of the historical facts relating to the discovery of this curious property of electro-deposition. They are to be found in works devoted to complete theoretical and historical dissertations upon the art, and therefore do not concern us in a purely practical book like this. It was soon found that the remarkable property spoken of could be turned to good account 'for every-day purposes. Copies of solid objects could be obtained; rare coins could be copied without the possibility of error; objects could, in fact, be multiplied to any extent without injury to the original. Woodcuts may be reproduced with the greatest accuracy in any quantity. Set-up type may be copied, and the copy printed from. Birds, fishes, leaves, insects, busts, and all imaginable kinds of solid objects are copied with the greatest fidelity. The art is known as *electrotyping.*

To obtain a copy of one face of a coin or medallion, it is only necessary to apply to its centre a ball of softened gutta-percha; this is passed outwards, so as to exclude all air, until the surface is covered, when the two are firmly pressed together in a vice, or beneath a weight.. As the guttapercha cools, a greater pressure should be applied, and when the moulding material is quite firm, the two may be separated. This faithful mould must now have fixed in it the end of a heated wire, near to the face edge: this will form the necessary con-

ductor. Blacklead is now brushed on until the surface is uniformly coated, and appears brightly polished, the wire and adjacent parts receiving a good share of attention. This mould may now be deposited upon in the usual way. The deposit will begin to form upon the wire, and will gradually creep all over the surface. The back being plain gutta-percha, no deposit can form upon it. When the deposition has attained a reasonable thickness, or that of brown paper, it may be removed from the mould, and its face will present a faithful copy of the original coin. It will be found more difficult to deposit upon gutta-percha articles coated with blacklead than upon plain metal direct. In such cases a greater tension of current will be necessary, and as many as three cells will be found to supply the required force.

These short directions embody the principle generally adopted in the production of the greater number of electrotypes. Different substances are used upon which to take an impression of the object. Wax is very frequently made use of, fusible alloy, an elastic glue and treacle compound, and plaster of Paris.

Gutta-percha for Moulding.—Perhaps this is the most generally useful material. The greatest care must be taken in copying woodcuts to make sure that the substance is perfectly free from grit or foreign substances of a hard nature, as the pressure is apt to destroy the cut. Gutta-percha cannot be used to surround any object, because it shrinks on

cooling. It is well adapted for flat surfaces. The softening should be done in boiling water, and the gutta-percha worked into a ball, which is then applied soft to the middle of the article and worked carefully out to the edges; this will expel all air. The pressure should be light at first, but as the substance cools it must be increased, and as the gutta-percha gets hard, great pressure ought to be applied to make up for the peculiar shrinking qualities of the material. A vice is very useful, and a screw-press may be used, or a heavy weight will serve the purpose. A compound of gutta-percha and marine glue is in some respects superior to gutta-percha. The gutta-percha is melted and the glue stirred in. Marine glue is made from caoutchouc and shellac, but it is best bought. When large surfaces of woodcuts are to be done, sheets of softened gutta-percha are generally used. A flat plate is put on the top, and the whole is well compressed. (See also p. 108.)

Fusible Metal " Clichee."—This is made by melting in a ladle five parts lead, then stir in three of tin, follow with eight of bismuth. Well mix, and granulate by pouring into water. This granulation should be continued for several times until the mixture is thoroughly made. This alloy will melt at the heat of boiling water, and may be used to copy wood articles without injury to them. The coin or article to be copied is surrounded by an edging of pasteboard, slightly oiled on the face, and the fusible alloy poured in, pressure being resorted

to as the alloy gets pasty. Care must be taken by
this method that the alloy is cleared of scum before
pouring. A better plan is to pour out the alloy
in a pill-box cover, or such-like receptacle, to clear
off the surface with a card, and when it gets pasty
suddenly press on the coin to be copied. A holder
should be attached by pitch to the coin.

Plaster of Paris.—This must be fresh, otherwise
it will fail to set. To insure the best work, it is
well to warm the plaster before commencing. A
flat dish of water should be prepared, and the
plaster sprinkled into it, then quickly pour off the
water, and work the plaster into a thin paste.
Pour it upon the oiled object, which should be
surrounded by a rim of pasteboard; air-bubbles
should be excluded. Allow it to set firmly, and
when removed bake it to expel all moisture. The
cast must be saturated with tallow or solid paraffin.
In doing this, prepare a shallow dish of the melted
substance, place the cast in it back downwards,
until the face shows that the soaking has reached
the face, when the cast should be removed. Too
much must not be allowed to soak in; if this does
happen, gently warm again until the excess is re-
moved. Allow to cool, and polish with blacklead
as usual.

Elastic Composition for Solid Objects.—This sub-
stance is made by soaking glue in water until soft,
melting in a glue-pot, and adding to it one-fourth
its weight of treacle. This composition will be
elastic when cool, and will be found suitable for ›

objects having much under-cutting. It may be used also to completely surround the object, which may be removed when the composition is set, by cutting the latter, which will spring back to its original position. It will be understood that this substance is unfitted for use in liquids direct. Prepare a vessel of sufficient capacity to hold the article to be copied—say a bronze bust. Let the latter be oiled to prevent adhesion; if it is hollow it should be filled with sand, and the opening closed with pasted stout paper. Oil the containing vessel within, and pour the hot mixture over the object until it is covered; allow to cool overnight. Shake out of the holder, and with a thin, sharp knife cut open the mould from top to bottom. An assistant can then withdraw the object while the operator gently holds the cut sides apart. This elastic mould is to be filled with a composition made up of bees'-wax 5 lbs., deer fat 5 lbs.; melt slowly together, add 8 oz. of a solution composed of bisulphide of carbon 7 oz., phosphorus ½ oz. This is to be poured in while as cool as possible consistent with its pouring well. When this duplicate of the original bust is removed from the elastic composition, it may be stood in a taper vessel, and covered with plaster of Paris; this is allowed to set, and the wax model run out by heat. The interior of the plaster cast is then washed out by

The Preparatory Solution.—Add to the above phosphorus solution ½ oz. of wax, 1 oz. spirit of turpentine, and a few grains of caoutchouc dis-

solved with an ounce of asphaltum in bisulphide of carbon.

The Conducting Solution.—Dissolve 1 dwt. of silver nitrate in a pint of water. To render more sure, also wash out with a solution of 4 grains gold chloride in a pint of water.

In depositing upon such work, an anode should be hung within the object, and a hole should be made at the lower end to allow of the solution escaping as it is poured in at the top. It is also common to fix a series of guiding wires to serve as anodes, but the best arrangement of these will be suggested by the shape of the interior. In all cases the guiding wires must be distributed about the surface, and lead to the main wire from the zinc plate.

The somewhat troublesome process avoids seams in the electrotype, but solid objects may be moulded from it in two portions by means of wax or plaster of Paris. Bed the article to half its depth in fine sand, and fix a few wires or wood pegs around the object so as to project. Then pour on the moulding substance, which may be wax, allow to set, reverse the sand-box, and shake out the sand ; trim the wax surface, leaving in the pegs, and• pour .on the other side. When set, separate the halves, polish up, after fixing wires, and deposit ; finally trim, and join the two halves with solder.

Wax composition for such work may be made thus :—Melt together three parts of yellow bees' wax

and one part of stearine. Some electrotypers add a little flake-white, but powdered blacklead is better, as it assists in the conducting operation. A great many small articles may be copied or moulded from in this composition. When coins are copied it is usual to do both faces, but not to join them to form a real duplicate.

New Method for Producing Fac-similes of Coins and Medals.—This method, which has proved very successful for such work, aims at the production of duplicate coins and medals in mixtures of tin and lead, or, better still, fusible alloy, or alloys containing bismuth. The coin is brushed over on both sides with turpentine in which a little bees'-wax has been dissolved. This is allowed to dry. A piece of good writing-paper is steeped in melted paraffin or in thin shellac varnish, and with a pair of compasses a circle of the same size as the coin is marked out. This disc is to be carefully and cleanly cut out with a sharp penknife, and the coin is to be fitted into the aperture thus made. If care is taken, the paper divider may be got upon its edge, and may be so fixed at the middle of this as to divide the coin into two parts or discs. There is no other preparation; the coin is simply supported in a square-bottomed stirrup of wire and deposited upon from an anode placed underneath. When one side has received a deposit, the other is to be turned, and this deposited upon. In this way two heavy and strong deposits may be laid in twenty-four hours or less. They will be separated

by the paper at the middle of the coin's periphery,
and if they do join a little underneath the paper,
they are easily separated with a sharp knife. By
heating the coatings rapidly, little difficulty will be
experienced in shaking the coin out, and in securing the two coatings in perfection. Their edges
are next filed round and even, and one of them is
placed in a pill-box cover just large enough to
hold it. A quantity of fusible alloy, well skimmed
and clean, is to be poured on the mould face,
skimmed quickly, and before it cools past a pasty
condition the other coating is quickly and firmly
pressed upon the alloy, so as to enclose a quantity
thick enough to fill the cavity. The excess will be
pressed out at the top, and may easily be separated
from the copy by cutting. This method gives a
very accurate copy with very little trouble. No
blackleading or other preparation is necessary in
the case of metallic coins or medals.

Coating of Ferns, Grass, Flowers, and Insects.—
Dried grasses, ferns, lace, and such objects may
be beautifully coated with copper. They are first
dipped for a few minutes in the preparatory solution
before spoken of, and then in the silver and gold
conducting solutions following it. The connection
with the conducting wire should be made before
dipping in the solutions. Silver and gold, as well
as copper, may be deposited upon these objects.

Electrotypes from engraved Steel Plates.—This
work requires considerable care, and the successful results are of great value. The steel plate has

its 'lines perfectly freed from ink. This is most
quickly done by boiling in solution of caustic
potash. Rinse out in boiling water, allow to cool,
and spread over the surface turpentine in which a
little bees'-wax has been dissolved ; clear off, and
allow to dry free from all dust. Place upon a flat
surface (preferably stone, or iron), and surround
with an edging of strip iron half an inch high.
The moulding composition is made of gutta-percha
2 parts, white wax 1 part, and lard 1 part; it will
require some time to properly mix, and for this
purpose a gentle and constant heat should be kept
up, with much stirring. Pour upon the plate,
allowing it to set for twelve hours. The mould
may be removed with care by cutting away any
overhanging parts. A little springing upwards
will release the surfaces. Great care is necessary
not to injure the mould. It is rendered conductive
by pouring over its surface a mixture of 1 ounce
phosphorus and 1 ounce of benzine in 2 quarts
of methylated spirit. The solution should be fil-
tered in case of sediment, and care is necessary to
observe that the plate is covered in every line by
gentle agitation ; pour off, and apply a solution of
nitrate of silver $\frac{1}{3}$ ounce, and glacial acetic acid
1 drachm, in a pint of pure alcohol. Gently agitate
over the surface of the mould until the silver is
seen to deposit all over; then pour off and wash
in distilled water. Four connecting rims (or a
greater number according to the size of plate)
should have been previously fixed in the edges of

the gutta-percha. Their ends should finish in
round rings or loops. All these loops are to be
connected by hooks to the main conducting wire.
As many as three cells should be employed to force
the deposit. A substantial layer of copper will be
deposited in a week, all over the plate, if the solu-
tion is properly supplied and worked with suffi-
cient battery power. A flat anode plate should
be employed for such surfaces, and its distance
from the mould may be from 2 to ½ inches. Care
is necessary to use only a filtered depositing solu-
tion, as any specks of dirt getting upon the mould
will destroy its use in printing. The necessary
separation may be easily made by warming the
copper plate. Any of the gutta-percha that may
remain (if too much heat has been applied), may
be removed with bisulphide of carbon. A little
rubbing with a soft brush or a piece of cotton wool
with the same liquid will separate any of the con-
ducting silver that may remain upon the electro-
type

"*Steel*"-*facing Electrotypes*.—This is a valuable
process, by which an exceedingly hard film of
electro-deposited iron is thrown upon the face of
an electrotype. The advantage is that the plate
will last much longer, by reason of its extreme
hardness of surface. It has also the advantage of
printing from better than copper itself, and will
easily take vermilion, while copper prints it only
indifferently. This process, properly conducted,
renders the wearing out of a plate a difficult

matter, while the iron may be dissolved off and
redeposited without in any way wearing the lines.
The deposit must be very thin, otherwise it will
spoil the fine lines, but there is little fear of
overdoing the "steel face" if the work is watched.
Before proceeding to deposit the iron, it is neces-
sary to perfectly clean out the lines of the plate,
and then to chemically clean the surface before
placing in the bath. Caustic potash will be found
useful for this, and only a very rapid dip of the
plate must be allowed to be given in the cleaning
mixture for copper; then well wash with water
only. (See *Preparation.*)

Steel-facing Engraved Plates.—The deposition of
iron being employed but rarely for any other pur-
pose than this, and because the facing of electro-
types is a matter of much practical import, I shall
confine my remarks upon *the deposition of iron* to
the instructions here given.

The double chloride of iron and ammonia has
been found to be the salt best fitted for the deposi-
tion of iron from a solution electrically. The author
adds, however, to this process particulars of a
solution resulting from some researches of his, and
from a modification of the process of Prof. Böttger.
To make the usual solution, dissolve clean iron
wire, in coils, in hydrochloric acid until the acid
is satisfied; use a gentle heat at the close of
operations, because the acid will be weak. For
every 58 grains of iron dissolved, add 53 grains of
ammonium chloride to the solution. I have found

that the addition of a proportion of glycerine to the solution diminishes its tendency to spoil. (*Sprague.*)

Another way is to dissolve 25 pounds of carbonate of ammonium in 17 gallons of water. The iron is to be dissolved into the solution by immersing in it a clean anode of charcoal iron, connected to the copper pole of a battery of three or four Bunsen cells. To the zinc pole attach another iron plate, and test for deposit by occasionally substituting a copper plate or the cathode.

To work the solution, let the anode be of charcoal iron, the current about three Bunsen cells. A deposit is not secured at once. It is necessary to immerse the engraved plate for a few minutes, take out, and brush well with fine whiting and water. Immerse again, scrub at the end of five minutes, and in four or five immersions a sufficient deposit will be secured. Keep the solution up by the addition of about half a pound of carbonate of ammonium every few days. The best results seem to be secured when the battery power is about three cells, and the surface of plates in the cells much larger than the anode or engraved plate. I have worked a solution (referred to above) which keeps better than the foregoing. Dissolve 5 pounds of ferro-cyanide of potassium, and 10 of the double tartrate of soda and potash in 20 gallons of water. Add now 1½ pounds of persulphate of iron, dissolved in a little water. Prussian blue is precipitated copiously. Now gently add, drop by drop, with stirring, a saturated solution of caustic soda until

the precipitate is redissolved and disappears. The liquid is now clear, and of a yellow tint, and may be used immediately.

"Steel-faced" plates should be very carefully washed in boiling water after removal from the plating solution. Then wash in cold water with brushing, dry off, rub with benzine, oil it, and rub again. If not at once required, set aside with a film of wax melted upon its surface.

Conducting Surfaces.—For general gutta-percha moulds, the best and cheapest conducting surface is the finest blacklead. That known as Nixey's is, perhaps, the best of common kinds. Ordinary house blacklead is almost useless, because it is so impure. Perhaps the best possible composition is fine gas carbon (battery carbon) pounded in a mortar to an impalpable powder. If this can be obtained fine enough, it answers better than most blackleads, and is cheap enough. The instrument makers generally keep a very fine quality of plumbago, which is, of course, more expensive than the commercial article. A good conducting surface being of the greatest importance, care should be taken to well polish it at every point, and to give particular attention to the conducting wire, so that the film of blacklead may commence *upon the wire*, and extend unbrokenly over the mould. The brush used should be of the softest kind. The blacklead should not be wetted, but brushed on dry, and the substance breathed upon while working up the surface. Exposing the coating to the evaporation

of spirit of wine will generally facilitate the
formation of a good surface. If there is under-
cutting, which cannot be well touched by the brush,
it will be best to do the whole surface over with the
preparatory phosphorus solution and silver and
gold solutions (or silver alone, according to the
value of the mould) mentioned before. In work of
importance, and of a large size, the process of black-
leading is greatly improved by gilding the black-
lead. To gild, dissolve 1 part of gold chloride in
100 parts of sulphuric ether, and shake into the
bottle, mixing well, 50 parts of the best plumbago;
expose the mixture to the sunlight, with frequent
stirring and shaking, until the ether has perfectly
evaporated. It is applied in the same manner as
blacklead. Plumbago may also be used with ad-
vantage in several moulding materials, to increase
their conductivity. It may also be mixed with the
finest white bronze powder. This has the property
(being tin, &c.) of coating itself by simple immersion
in the solution, and greatly aiding the formation of
a first deposit—it should be used chiefly upon large
moulds. *Wires* must be carefully fixed in mould-
ing materials; in gutta-percha by warming and
pressing into the surface, and in plaster by arrang-
ing for fixing before the plaster is poured, or
while it is yet soft. *Guiding wires* should be led
from the main wire upon all surfaces larger than
two inches in diameter. They should lead into the
margin of the mould, and should be blackleaded over;
such wires should be finer than the main ones for con-

venience of twisting, and the ends of some of them should touch deeply cut parts of the mould, until a deposit is there formed; always selecting such points as are not likely to be defaced by the wire until a coating is secured. In working with plates, such as copper plates, to be faced, the wire is to be soldered to the back.

A *non-conducting* surface is also required in electrotyping, for "stopping" off the deposit where it is not required. Copal varnish will be found to answer all purposes in the sulphate solution, and in the hot cyanide one the best quality of the same, with the addition of rouge, allowing to dry well. Solid paraffin is useful in cold solutions, and shellac varnish may be employed. Accidental finger-marks of blacklead should be varnished over, as they are very troublesome if in contact with the main coat or the wire.

Electrotyping Set-up Type.—This process is somewhat similar to the reproduction of woodcuts. The type is blackleaded, and the impression taken as usual. Care should be taken that the mould and anode are not nearer together than about 3 inches, because the deposit finds difficulty in spreading to a strong deposit in deep lines. American printers employ this method of reproduction very extensively, and even in England stereotyping is to a certain extent giving way to it. The reproduction lasts longer than one in "stereo" metal, and the copper delivers the ink more readily.

Hints on depositing Copper.—The battery power

required will depend in great degree upon the nature of conducting surface. A plate of copper or other metal to be deposited upon, can be coated in a few minutes, and there is no trouble in making the deposit spread. But blackleaded surfaces, especially of gutta-percha, plaster of Paris, and wax, are sometimes troublesome, and are always somewhat difficult to drive a deposit over. Tension in the battery current is what is necessary in spreading deposits upon refractory surfaces. This means the joining up of a number of cells in series. The size of their plates is not of so much importance in forcing the deposit. In laying copper upon metallic objects three cells will be ample, but in dealing with gutta-percha coated with blacklead, as many as five or six may be found necessary if the conducting-wire and branches from it are not very carefully fixed, and the plumbago coating well done. The anode in such cases should even have a smaller surface than the article. As soon, however, as a *complete coating*, however thin, is obtained, there is no use in wasting battery power, unless the work is needed immediately ; but in laying the main deposit, ordinary conditions should be adhered to—the battery plates should be as large as the anode, the anode as large as the article, and the distance between the anode and article made as small as possible. Rapid working is never attained to in baths where the anode and mould are far separated. The distances must, however, be greater in the case of undercut moulds, or those

with pits, than in coppering flat plates or ordinary
woodcut work.   Battery power should be regulated
to the work, but current may be regulated very
easily by the distance apart.

Rapid Practical Electrotyping.—I add to the fore-
going remarks some useful information which will
serve as a guide to, or explanation of, the way by
which the rapid and successful electrotypes from
set-up type and woodcuts are produced for such
high-class newspapers as the *Illustrated London
News,' Graphic,* and other papers, where the illus-
trations are prepared, cut in wood, electrotyped, and
steel-faced, in the shortest possible time to meet the
exigencies of the public wants.   In different shops,
different processes are adopted, but the result is
not materially influenced.

To commence work, the type or the wood block
is thoroughly cleaned by means of turpentine and
a stiff brush.   It is then dried, spontaneously if
there is time, or by means of boxwood or mahogany
sawdust if not.   It is now dusted with the finest-
powdered and sifted plumbago.   To prepare the
moulding material, which is simply bees'-wax and
finely sifted plumbago, melt good bees'-wax in a
thick copper pan, and stir in the plumbago very
slowly, to insure a very intimate mixture.   The
best guide to the quantity will be the thickness of
the mass: it must not get quite pasty, and by
allowing a little more heat, it must be quite fluid.
Keep the mixture at a good temperature under
boiling, and stir well—this is to insure the getting

rid of all moisture and air-bubbles. For pouring the wax in, " chases " as they are called, or shallow dishes of pewter or stereo metal are used. They are of the required size to hold the work, and about a fourth of an inch deep; they should have end projections, with holes for hooks to hang in the vat.' The wax-moulding mixture, still very hot, is poured into the chase, and allowed to spread of itself from one corner. The chase is then placed on a level surface, and allowed to become partly cool. As soon as the wax is seen to have upon its surface a skin, and begins to make cracks therein, gently skim the surface. Allow the wax to become partly set, and carefully lift on to it the prepared block or type. Place in the press, and give a gentle squeeze. Lift off again, and see if the block face has taken up any wax; if not, dust very thinly again with plumbago, and replace. Care must be taken, if no proper gauge-marks are made beforehand, to so guide the sense of touch that the block may "fall fair," or into its proper position. Now apply a very heavy pressure in the press; the impression is now technically (in some shops) called a " squeeze." Remove and examine the wax. It should be a beautifully perfect copy in *intaglio* of the block or type. Dust the " squeeze ". with fine plumbago, and polish up with a soft brush; see that all loose or large particles are blown off by the breath, and observe that a good connection of plumbago is made to the " chase " side.

The mould is now ready to be " hooked " and hung

in the solution to a rod connected to the zinc end of the battery. The depositing trough employed is of oak, well jointed, and lined with lead, or asphalt, or marine glue. Its size is usually about four feet long, with depth and breadth of two feet and eighteen inches respectively. The usual copper solution is made, per gallon, of one pound good copper sulphate, and one pound of sulphuric acid—dissolve the salt first; gelatine may be added to make the mixture keep better.

When a *battery* is used it is commonly of the Smee type—zinc and platinised silver plates. As many as twelve zinc and silver plates are used—each a foot square, placed close together, and the trough filled with weak sulphuric acid—1 acid to 100 of water. All the zinc plates go to one wire, and all the silvers to the other. This battery usually serves with one charge for about a week, and is recharged by drawing off the old liquid with a syphon. It acts simply as one cell of large surface, as all the plates go into the common oak trough—lined with lead or marine glue.

The *anodes* are of thick sheet copper, a little larger than the chases to be coppered. The mould is hung in the solution a few inches from the anode face. In about ten minutes the deposit is observed to slowly spread towards the centre. When this is seen, a look-out should be made for pinholes, which are caused by air-bubbles, and may be prevented from forming by brushing off. If all is in good order, the copper will be thick enough in from

seven to ten hours. If time is short, keep the anode nearest to the chase as soon as a complete deposit is formed. This will press matters on quickly. The deposit will be thick enough if a little stouter than brown paper. As a matter of fact the deposits may even be thrown on in much less than ten hours, if two cells in series are used, and if the surface of their plates is as great as that of the "squeeze," and even greater, it is surprising what may be done in six hours. As soon as the complete coating is laid, there should be no further trouble with the deposition until it is thick enough. In warm weather the work will be done in less time than in cold.

When all is ready, remove the chase, wash with water, cut away any copper round the edges which may prevent the ready removal of the deposit, and heat the chase over the gas, to loosen the wax, when the electrotype may be lifted carefully off. Place it face downwards on an iron tray with handles, and brush over with soldering spirit (hydrochloric acid saturated with zinc), and sprinkle with cuttings of solder. Place the tray in a flat vessel of melted stereotype metal, until the solder melts, when it may be spread with a soft rag and spirit. This is called "tinning" the electro. Remove the tray, and arrange a kind of framework or edging of iron bars around the copy to hold in the stereotype metal which is to form a backing. Pour on the clean metal to a depth dependent upon the size of electrotype. For deposits a foot square

the backing should be half an inch or more thick, and the smallest electrotype should have a fourth of an inch of backing. Allow to set, and cut off with the circular saw the edge-metal. Place in the planing machine, and plane down to gauge.

An examination should now be made to find if there are any depressions on the plate, or other defects that might prevent the printing being good. Depressions are brought up on the face by taps from behind. The edges are filed bevel to " clear," and the plate is finally mounted on a block of mahogany, or oak, if its size is considerable. This block is, of course, gauged to the height of the type. A little practice will enable an ordinary intelligent man to turn out first-rate electrotypes by this method.

The foregoing short directions in the art of electro-typing must not be regarded as exhaustive. Very little has been said of the use of the dynamo-electric machine in such work. These machines are now, however, rapidly superseding batteries. The work is accomplished much more quickly by their aid. For fuller and more detailed informa‐ tion the reader is referred to the author's treatise on " Electrotyping."

CHAPTER V.

Deposition of Silver.

Its Salts.—Of the many salts of silver, the nitrate, oxide, chloride, and sulphide are the most common.

The *nitrate* is the most generally useful of these salts, and it is important that the electro-plater should be conversant with its manufacture from the metal itself, as it is very usual to find it prepared altogether in the factory, although it may be purchased for very little more than the value of the metal it contains.

The text-books often direct thus :—Dissolve grain or sheet silver in nitric acid and evaporate ; but this is widely different from what is necessary to be done in practice. The nitric acid must be pure, and must have a specific gravity of at least 1·420, otherwise it will not dissolve silver with sufficient rapidity to insure success. It should be diluted with one volume of filtered rain-water to four volumes of the acid. This mixture must be warmed to about 100° F., and the silver, in sheet or grain, added to it slowly and with care, not to cause violent boiling. The operation should be conducted in a rather tall vessel, so that the froth may not be lost. Care

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should be taken to have the neighbourhood well
ventilated, or to conduct the operation in the open
air, and standing over the vessel should be care-
fully avoided by the operator, the fumes of nitric
acid being very injurious. The silver should be
cut into thin slips in case of sheet being used.
Should the mixture become unmanageable by boil-
ing over, cool it down by the addition of a little
cold water, and add the silver more slowly. As
soon as the acid is satisfied, and will dissolve no
more of the metal, evaporate it by placing the
vessel in boiling water, or applying heat to it
directly. Carry this on until the bulk is insig-
nificant, and set aside to cool and crystallize. It is
best to do this in the dark, or in an opaque vessel.
The resulting colourless crystals are nitrate of silver,
or "lunar caustic." They should be free from the
odour of nitric acid, should contain as much as $63\frac{1}{2}$
per cent. of silver, and should be perfectly soluble
in distilled water. In purchasing nitrate of silver,
care should be taken to test its value before buying
largely. This is best done by fusing at red heat with
borax in a common crucible, washing and weighing
the metal, when the above value should be ex-
hibited ; or it may, of course, be done by pre-
cipitating a solution of it by dilute hydrochloric
acid, washing and drying the precipitate. Nitrate
of silver should be kept in an opaque bottle, or in a
dark place, and care must be taken not to handle
it too freely with the naked hands. Its price varies
as that of silver, but it may generally be obtained

at 4s. per oz. It is a by-product in various large operations at chemical works.

Oxide of silver is generally prepared by adding a solution of caustic soda to one of the silver nitrate, until all the metal is precipitated as oxide. This brown powder is washed and filtered. It is similarly obtained by precipitation, with clear lime-water and caustic potash. The wash-waters should be preserved, as they contain a little of the oxide. Care must be taken in the use of caustic potash, as severe sores result from touching it with the naked hands.

Chloride of silver may be readily obtained from a solution of the nitrate by precipitating with common salt, or dilute hydrochloric acid. This should be done with stirring, and the precipitate allowed to settle slowly. It is silver chloride, a white flocculent powder, and must be kept in the dark. The presence of impurities in the silver, especially copper, is very quickly detected by a pink appearance of the precipitate.

Cyanide of silver may be readily prepared by adding a solution of cyanide of potassium to one of the silver nitrate. The solution of potassium cyanide may be of strength about 2 oz. to the pint. It should be added to the silver solution slowly, with stirring, until no further precipitate is observed. The resulting salt should be white, and is cyanide of silver. It is quite insoluble in water, but will freely dissolve in most of the cyanide solutions, and in hyposulphite of soda solution, sal-ammoniac,

and ferro-cyanide of potassium. The same salt may be obtained from the oxide or chloride of silver, but the nitrate produces the purest cyanide.

Double Cyanide of Silver and Potassium.—This is by far the most generally useful of the salts in silver-plating solutions; and it is only necessary to dissolve it in water to at any time obtain a plating solution for the battery process.

Sixty-five parts of potassium cyanide in solution will be required to convert into the double salt 134 parts of the silver salt. This is really the plating solution, and only needs a slight excess of the potassium cyanide to render it suited for work. But of this solution further information is given in this chapter.

Simple, or Immersion Silvering.—This art is daily becoming of more importance, especially to amateurs. The methods here given are selected from those I have myself used, and may generally be relied upon to produce good coatings if the directions are rigidly adhered to. The solutions are peculiarly applicable to such articles as brooches, buttons, hooks and eyes, watch-chains, and articles even as large as forks, tea-spoons, toast-racks, and liquor labels.

Strict cleanliness must, of course, be observed with the articles, otherwise the coatings cannot be depended upon.

The simplest possible solution is that of the chloride of silver in water, with the addition of common salt. This is well suited to the silvering

of dial-plates, and such goods as may be varnished.
Brass goods, when properly cleaned, take a good
coating, and may be exposed to considerable fric-
tion without injury. The mixture should not be
made thinner than cream, and should be applied
by rubbing upon the previously wetted article with
a piece of cork, or a rubber made of rag upon a
wooden handle. The rubbing must be continued
until the surface is uniformly silvered, when the
article should be washed, dried in sawdust, and if
possible varnished.

Another solution, yielding a better coating more
readily, is made up of chloride of silver, 1 part;
washing soda (common), 3 parts; common salt, $1\frac{1}{4}$
parts, mixed together with a little warm water
until as thin as cream. It will improve as it is
used, and may be replenished, as it gets exhausted,
with a little chloride of silver in solution.

Another solution is composed of silver chloride,
1 part; common salt, 8 parts; alum, 2 parts; cream
of tartar, 8 parts. These are mixed together with
warm water. When the surface of the article will
admit of it, rubbing should be resorted to, and in
the case of goods exhibiting much intricacy of
pattern the solution should be thinner, and the
motion more vigorous. In no case should the
fingers be used to apply such compounds. Soft
tooth-brushes are useful, as are also pads of cotton
or sponge.

A simple immersion solution, the particulars of
which are due to M. Roseleur, is well known to

produce the best possible simple immersion coat-
ings. Its preparation is, however, somewhat trouble-
some, although the labour is well repaid. Dissolve
4 parts of washing soda in 5 parts of water in a
deep vessel. Place in the bottom also a layer of
mercury about $\frac{1}{4}$ inch deep, and into this let the
end of a glass tube dip, through which pass sul-
phuretted hydrogen gas (see process p. 44), until
the solution is found to redden blue litmus-paper,
when the passage of gas must be stopped. The
mercury is simply to prevent the tube end from
getting chocked up with crystals, and with care
might be dispensed with. Set the solution aside for
twenty-four hours, pour off the liquid portion, stir,
and test again with the litmus-paper. If decided
acidity is observed still, by the paper becoming
quite red, add more crystals until the paper is only
made violet. If no sign of acidity is observed, it is
too alkaline, and more gas must be passed through
it. All that now remains to be done is to add the
necessary silver, and this is best done by putting
in a solution (saturated) of silver nitrate, watching
the result. A precipitate will be formed, which
will almost at once dissolve again, and as long
as the solution redissolves the silver, it should
be added, until the redissolution becomes slug-
gish, when the mixture is ready for working.
This solution, if properly made, will be found to
produce a *thick* coating of silver, and will work
for many months. But its only slightly acid
condition must be preserved by the addition of

either gas or soda; with silver when this is re-
quired.

There is no necessity to rub this mixture upon
the articles. They must be left in it, moving about
occasionally, until the required coating is secured.
The coating is well suited to brass, copper, bronze,
and other goods of the cheap description.

A solution for simple immersion, to be used at a
boiling temperature, is, perhaps, better suited to
the general run of small goods than any of the
foregoing. It is composed of water, 1 gallon;
cyanide of potassium, 1 pound; and 3 ounces of
nitrate of silver. It is usual to immerse the articles
in a basket, and to shake about until completely
silvered. Or any of the foregoing solutions may
be used with advantage at a boiling temperature.
An enamelled iron vessel should, if possible, be em-
ployed. Care should be taken that metals differing
so much in their nature as copper and zinc are not
immersed in such solutions, because a voltaic tend-
ency is at once set up, and zinc will probably be
deposited upon the other goods. It is found that a
solution in which much copper has been silvered,
and is green in consequence, works better than a
new one. It should be noted that the greater the
volume of solution, the better and quicker the re-
sults. For practical or professional purposes the
solution should never, if possible, contain less than
a gallon of water, and two gallons is a better work-
ing volume. The cost of this class of silvering is
very small, because the labour is small, and the

coatings cannot easily be made thicker than tissue-
paper, except in the solution of M. Roseleur,
which, when properly made and attended to, may
yield plating of a very durable nature, and which
might bear favourable comparison with electro-
plating itself. A satisfactory explanation of the
increasing thickness of deposit in M. Roseleur's
solution was not at first easy to find. The plating
goes on without any apparent electrical action
until the desired thickness is laid, and the same
law which causes the metal to act thus also causes
the introduction of a little drawback in the work-
ing—for the silver is in part deposited upon the
sides of the vessel. Of course there is no waste
here, but attention must be paid to the amount of
silver so abstracted, so that the solution may not
be allowed to get poor in metal and unfit for work.

The obvious explanation is a chemical property
of the liquid foreign to common solutions. In
common simple solutions the action of plating is
undoubtedly electrical, by which a portion of the
immersed surface is dissolved, which, setting up
electrical disturbance, causes its equivalent of silver
to be deposited. This goes on until the article is
quite protected from further dissolution, when the
plating must and does stop, leaving only a thin
coat. But in the peculiar solution of which we
have spoken the action is chemical. Sulphurous
anhydride from the silver sulphite absorbs oxygen
to form sulphuric anhydride, thus setting the silver
free ; and this metal will deposit itself upon the

nearest object, regardless of its nature, even upon
the porcelain vessel. It is probable that the sul-
phuric anhydride, as suggested by Mr. Gore, com-
bines with some of the soda of the undecomposed
portion of the sulphite, liberates sulphurous anhy-
dride, and forms sulphate and bisulphite of sodium.
(Comp. *Silvering of Specula.*)

Silvering Glass Specula.—Although the following
process is seldom touched upon in works of this
class, I have thought, judging from the number of
inquiries addressed to me about it, that it may
meet a general want of amateurs. It may be
needless to note that the process, albeit fitted for
other work, is mainly arranged for the specula of
reflecting telescopes and concave mirrors. It be-
longs to the subject of simple silvering, and I place
it for distinction at the end of the usual processes.

Four separate solutions are required :—

Solution *a* :—Dissolve 175 grains of pure silver
nitrate (crystallized) in 10 oz. of distilled water.

Solution *b* :—Dissolve 262 grains of pure nitrate
of ammonia in 10 oz. of distilled water.

Solution *c* :—Dissolve 1 oz. of pure potash (pre-
pared by alcohol) in 10 oz. of distilled water.

Solution *d* :—Dissolve ½ oz. of pure sugar-candy
in 5 oz. of distilled water, then add 52 grains of
tartaric acid, and boil in a glass flask for ten
minutes. When cold add 1 oz. of alcohol, and
then dilute with distilled water, so as to make up
the volume to 10 oz. for use in winter, and to 12 oz.
for use in summer.

These solutions must not be mixed together until they are required for use, but as given they may be kept separately, and in a dark place, indefinitely.

For use, pour into a graduated measure 4 oz. of solution *a*, and then add to it 4 oz. of solution *b*—call this mixture A.

Into a second measure—or see that the first is clean—pour first 4 oz. of solution *c*, and then add to it 4 oz. of solution *d*—call this mixture B.

When actually required, pour solution A into the silvering, vessel, and then stir in solution B with a glass rod, so that the mixture may be good. The effect will indicate whether or not the solu-tions are properly made. The mixture should not at first lose transparency, but should begin to change colour in about thirty seconds, first to a pinkish yellow, then brownish, and finally to a fine black. Just prior to the solution turning pink, the surface to be silvered is to be lowered into it.

This is Martin's process, and with care will be found to afford more certain results than that of Ackland, Draper, or the Sugar of Milk, particulars of which it will be unnecessary to give here.

The vessel in which it is intended to silver the speculum should be sufficiently deep to allow about half an inch depth of liquid between the face of the mirror and the bottom of the dish. In diameter the vessel should be at least 1 inch larger than the speculum—it is needless to say that this vessel must be chemically clean. To prepare the work, all extraneous dirt must be removed carefully,

if possible by warm water. As the mirror is to be
supported face downwards in the silvering vessel, a
cross-piece of wood should be made to go across
the top of the latter. It is best to cement this to
the back of the speculum with pitch. Let the glass
be moistened with turpentine, and evaporate this
nearly off before applying the pitch, to insure the
adhesion of the latter. If the silvering vessel is too
deep, place a block of wood between the speculum
back and the wood strip, so that about half an inch of
space may be between the mirror and the flat bottom.
This will permit of the volume of liquid required to
be known, by filling with water and measuring.

To chemically clean the mirror directions are
here given, because they could not be conveniently
classed with those relating to metals. A test-tube
is convenient as a holder for the rubbing-pad. Its
diameter should be about half an inch or over for
large specula. Fill it with cotton wool, allowing a
pad to project. Pour strong nitric acid upon the
mirror face, and rapidly rub it well over the surface
with the cotton wool. Now dilute the acid by the
addition of a little distilled water, and again rub
well all over the surface. Run water upon the
speculum for a few minutes until the acid is well
washed off, and finally well rinse with distilled
water. If the cleaning has been perfectly done, the
water will appear to cleave to the entire surface.
If purity of surface cannot be secured by the use of
nitric acid, dry up the surface with a perfectly clean
linen cloth, and apply a mixture of potash in water

(1 oz. in 10) with an equal volume of alcohol.
Spread as before with a new pad, dilute the mix-
ture as before, and well rub. Finally rinse the
surface with a liberal quantity of distilled water,
and keep the speculum face downwards in distilled
water until the silvering bath is ready.

As soon as the solution is observed to begin
changing colour, let the speculum be immersed. It
is necessary to exercise care in doing this. It must be
slipped into the watery solution edge first. Care is
likewise necessary in removing any water that may
remain upon the speculum back, as it is liable by
falling down to give rise to streaks in the silvering.
Well note that no spots of dust get between the
speculum face and the solution, and that all air-
bubbles are broken. Keep the solution in gentle
motion for the first few minutes, until the film
begins to assume a definite thickness. The mirror
may also be gently rotated. It is of the utmost
importance that the surface should not be separated
from the liquid by any accident during the forma-
tion of the film, as the almost certain consequence
is a streak, or break of continuity in the silvering.
It will be unnecessary to continue the agitation
constantly after the film is laid. For purposes of
observation the silvering vessel should be of glass.
Allow the deposition to go on until all the silver
in solution has been deposited. This may be
ascertained by the solution being clean, and it will
be necessary to break through the silver film at the
edge to observe this. In warm weather the de-

position is much more rapid than in cold. See
that the mirror is not allowed to remain longer in
the liquid than is absolutely necessary, as there is a
tendency to lay a whitish film upon the silver after
the solution is exhausted of its metal.

Well wash the surface after removal by allowing
distilled water to run over it. After washing, let
the surface dry, by resting the speculum with blot-
ting-paper beneath to absorb all water running off.
It is best to get this drying done quickly, by means
of a draught of air, but see that heating to attain
this object is carefully avoided. The drying may
be assisted by absorbing with blotting-paper the
water around the edges. In a damp atmosphere it
is advisable, as suggested by Messrs. Horne and
Thornthwaite, to drive off remaining moisture by
exposing the mirror to a *slight* warmth at some
distance from a fire. This should be done just
before polishing.

Finishing the film requires some care, above all
to avoid grit getting into the polishing pads.
Make a pair of these by filling two pieces of extra
soft wash-leather about six inches square loosely
with cotton wool, and tying them into balls with
twine. Carefully dust the film with camel-hair
brush or cotton wool, and then rub over it with
one of the pads in short circular strokes four or
five times. This treatment will give strength to
the film. Spread and examine some rouge upon
clean paper, dust the other pad with it, and go over
the surface as before until the polishing is perfect.

This pad should be kept for 'future use in a bottle or other place, free from dust.

All glass surfaces may be silvered in this way, but the directions just given are peculiarly applicable to specula.

Silver-Plating by the Battery Process.—Numerous patents were taken out many years ago for new solutions for silver deposition. They are all more or less valueless, as experience has shown, and time has also conclusively proved to practical men, that the double cyanide of silver and potassium, dissolved in water, afforded the best working solution.

Cyanide of silver dissolved in cyanide of potassium is, however, a very wide definition of the working solution. For the benefit of those who require the plainest possible instructions in making up silver solutions, my remarks are divested of all chemical formulæ, so that the merest amateur may produce and work silvering baths almost as successfully as the every-day plater.

It is common to suppose that the silver to be used must necessarily be pure. This is not so, as ordinary commercial silver, having copper in alloy, works very well. I shall suppose that the nitrate is made from the raw metal by the operator himself. Particulars as to actual working quantities would be out of place here, when one reader may require a quart, and another a hundred gallons of solution.

The weight of silver in each gallon of really good plating solution should be two and a half ounces.

This will serve as a guide to the weight of metal

required for any given volume of solution. It will
be seen further on that this weight to a gallon may
be deviated from considerably under certain con-
ditions, but there is no kind of plating that cannot
be successfully accomplished with this metal to the
gallon. I have plated well with one ounce to the
gallon, and also with five ounces, but in such cases
ordinary current and size of anode had to be de-
parted from ; and little satisfaction results from
working so widely of the composition which
lengthy experience has taught the plater to be
the best. For poor kinds of work, of the large
class, less metal may be used, and more for baths
required to be worked richly and quickly.

In dissolving the silver to form nitrate it ought to
be cut into very narrow slips. If sheet is em-
ployed, this may be conveniently done with a
pair of scissors; but if what is known as grain
silver is used, further division is unnecessary.

Take two parts of silver, add it gradually to a
warm mixture of four parts of strong nitric acid
and one part of water. Let this be done in a large
stoneware or glass vessel. The brown fumes of
nitrous anhydride are given off in great quantity,
and as they are very injurious, they should be
carried off by a vent, or the whole operation should
be conducted in the open air. It may be useful to
state that the weights of silver and nitric acid above
given are good for good silver and the best nitric
acid, but of a poorer quality of acid more must be
used to completely dissolve the silver, and the heat

must be greater. The action must be regulated by more or less silver, or a little water if it becomes too violent so as to boil over. If too little acid is employed, the fact will be indicated by its ceasing to act upon the silver. When the metal is completely dissolved, evaporate the liquid portion nearly to dryness by boiling, and set aside the residue to cool and crystallize. Dissolve the resulting salt, nitrate of silver, in distilled or filtered rain-water, allowing nearly a gallon to each ounce of salt. Prepare also a solution, of equal bulk, or less, of cyanide of potassium in distilled or filtered rain-water. If the potassium salt is very good (over 60 per cent.: see *Chemicals*), half an ounce to the pint will be strong enough, and if weaker one ounce. Add this solution, with constant stirring, until a precipitate of cyanide of silver ceases to fall as a white powder. Waste must be avoided in doing this, for if too much is added hastily, some of the silver cyanide will redissolve, and will be difficult to find again. To totally steer clear of the possibility of waste, add the potassium cyanide solution very slowly, and cease instantly the white precipitate ceases to fall. If it is suspected that too much of the cyanide solution had been stirred in, add a little more silver nitrate, which will descend as a white powder as before, as long as any excess of potassium cyanide is present. Allow the liquid to settle well down until quite clear. Pour off the clear liquid, and dash in more distilled or filtered rain-water, briskly stirring and allowing to settle,

after which pour off again. Repeat this washing
a few, times, with care not to lose silver in so
doing. Prepare next another solution of cyanide
of potassium (from three-fourths to one and a half
ounces to the pint), of bulk half a gallon to each
ounce of the silver cyanide, and add it to the latter
with constant stirring, allowing time for dissolution,
until all the salt is dissolved; then dilute the whole
to about half a gallon to the ounce of cyanide, with
distilled water, and add about one ounce to the
gallon of potassium cyanide to form *free* cyanide,
otherwise the solution would fail to dissolve its
anode with sufficient freedom. It is well after-
wards to filter the solution, through calico, into the
silvering vessel.

These are all the necessary directions for the
preparation of a solution by the chemical process
direct from the metal. It will be found best to
work from the metal in large operations, but for
small volumes it will prove more advantageous to
purchase the silver as nitrate, testing for quality, if
accuracy is desired, as before directed (see *Nitrate
of Silver*). All the wash-waters or residuary liquids
should be preserved when the operations are
large, because they generally contain some of the
silver in solution; and, if any insoluble substances
appear in making the solution, they should be pre-
served.

Several writers mention a method of preparing
the cyanide of silver from a solution of the nitrate
by passing into it hydrocyanic acid gas. Although

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this may yield a silver cyanide of remarkable purity, it is exceedingly dangerous, especially in the hands of unskilled operators; the gas being diffusive, is liable to be inhaled, with fatal results. Moreover, the trouble is very much greater, and the same result in purity may be attained to by using cyanide of potassium of 85 per cent. purity and upwards without danger. It may, however, be employed, and perhaps with advantage, by very careful platers who have by them a stock of otherwise useless ferro-cyanide of potassium ("yellow prussiate of potash" of the shops) and sulphuric acid. The ferro-cyanide is coarsely pounded, passed into a glass flask, mixed with slightly dilute sulphuric acid, and heated, the gas being led off by a tube into the nitrate of silver solution, which must be stirred until all the silver is down as cyanide. All this should be done in the open air or where a good draught can be secured, and the greatest possible care should be taken not to inhale any of the gas. This same process is very useful in recovering from spent solutions some of their metals, but the manipulation is slightly different.

Hyposulphite of silver in solution of hyposulphite of soda will deposit silver fairly well, but the solution is only fitted for short experiments, as it spoils by being exposed to light. Many writers recommend it, but I cannot do so, as its silver, although laid easily with the smallest battery power, is so soon precipitated to the bottom of the vessel on exposure to light. For short experiments or

small pieces of work in the hands of amateurs, it
may be made up by dissolving the chloride of
silver in a solution of hyposulphite of sodium.

Ferro-cyanide of potassium is used to a limited
extent by some platers instead of the cyanide. Its
use cannot be recommended, as it loads the solution
with a foreign salt, and it would appear that the
silver deposited from such a solution is very liable
to strip. It is, therefore, false economy to employ
the yellow prussiate of potash.

It is not uncommon to find cyanide solutions
made up chemically, and differently from that de-
scribed. It is not uncommon, for example, to simply
make the solution by stirring the oxide or carbonate
of silver into a solution of potassium cyanide ; and
although this will enable the operator to dispense
with the use of cyanide of potassium in precipitat-
ing the silver from its solution, and to employ in
its stead caustic potash, carbonate of potash, and
even common salt, it has nothing to recommend it,
and is, again, an example of false economy. It is
still necessary to use the same amount of potassium
cyanide as by the ordinary cyanide process. When
oxide of silver, for example, is placed in a solution
of cyanide of potassium, it needs one equivalent of
cyanide to convert it into cyanide of silver, and
another to dissolve this cyanide of silver as before.
And it is, moreover, working in the dark, although
the plan may be useful to those who do not wish
much handling of potassium cyanide. But such
solutions never work satisfactorily for a great length

of time, and have many obstructions in the shape
of useless potassium salts, which may or may not
do harm according to the condition in which the
solution is to be worked. Such a salt as oxide of
silver going into a solution of potassium cyanide
must lose its oxygen, which simply goes to form
with the potash salt caustic potash, which is at
least of no use, while the potassium chloride result-
ing from so foolish a mixture as chloride of silver
with the cyanide solution, almost stops successful
working and dissolution of the anode. These bad
effects are not apparent at once, but increase as the
work goes on.

The standard cyanide solution may also be made
by the battery process; that is, instead of the silver
being prepared chemically first, it may be dissolved
into the solution by the current from a cell or two
of any type of battery. This process is exceedingly
handy to amateurs and others requiring only a
small volume of the solution, and is certainly
preferable in such cases to special chemical prepa-
ration; also where all operative skill is wanting,
because no loss of metal can result, and there are
no wash-waters to preserve. It is only necessary
to prepare a solution of potassium cyanide, of
strength about four ounces (quality at least 50 per
cent.) to the gallon. Then suspend a large sheet of
silver to dissolve, and connect it to the copper or
carbon pole of the cells. Suspend likewise a bright
silver strip a few inches off, connect to the zinc pole,
and thus pass current until about 1½ oz. of silver to

the gallon has disappeared. If it is required to
have more metal than this, add more cyanide in
solution, or less if a poorer solution is required.
The best guide is to pass the current until the cathode
receives a good coating of silver in a few minutes.
This solution may be worked with the dissolving
sheet as an anode, in the same way as large volumes
are worked. Unless the actual percentage of
actual cyanide be known, it is difficult to state the
quantity of free cyanide necessary. A good test is
to work the solution with the anode for a little time,
and if the anode is not bright and clean, too little
free cyanide may be suspected, and more should be
added. As a matter of course a strong current
should be employed in making such solutions. It
is objected to this method that it sets free caustic
potash in the liquid. This is true, and it eventually,
by absorption of carbonic acid from the air, becomes
carbonate of potash. It does no harm as far as
experience has shown, but it does no good. It is
certainly more objectionable in large volumes of
liquid than in small ones. Notwithstanding this,
many electro-platers make up their solution by the
battery process. It proves to be exceedingly useful
to those who take the trouble to test the cyanide
employed. There is also an advantage in this way
of making up a solution, as very little trouble is
appreciated in giving to it just as much metal as
may be wanted. The equivalent of cyanide of
potassium is 65, so that 65 parts of the *pure* cyanide
ought to be in the solution with 134 parts (the

equivalent of cyanide of silver) of silver salt. Over
and above' this there should be present about 50
parts more of potassium to form free cyanide, with-
out which it would be impossible to work.

It is not uncommon to employ two solutions in
silver-plating, especially in treating the cheapest
kind of goods. Where the standard work is really
composed of inferior articles, it is probably more
economical to first " whiten," as it is termed, and
then finish in another liquid. The process is well
suited for cheap and rapid working. To make a
" whitening " solution, dissolve about two pounds
of cyanide of potassium (over 50 per cent.) in one
gallon of rain-water ; add afterwards half a pound
of carbonate of soda, with stirring; and add last,
four ounces of cyanide of silver. Whiten the
articles in this with a current of high tension—
five to eight Smee cells, six Bunsens, allowing
the anode to be quite near to the goods. As a
rule, when the current is strong, they will whiten
instantly, and are to be removed for finish-
ing in the other solution, which is made up by
dissolving four ounces of cyanide of potassium and
two of cyanide of silver in a gallon of distilled
or filtered rain-water. Employ a current of lower
tension to finish, and let the cell be large, so that
the work may not go on so rapidly, but let the
anode be near to the articles. The poorer kinds
of articles may thus be silvered without the neces-
sity to amalgamate or "quick" in a mercury
solution. (See *Preparation.*)

It will be˙ unnecessary to extend this portion of
. the work by quoting the solutions of the various
patentees.   They are all, curiously enough, inferior
to the standard cyanide .solution in working, and
the greater part of them were devised before platers
had become sufficiently acquainted˙with the good
properties of the double cyanide of potassium and
silver.   I leave the particulars I have given of this
solution in the plater's hands with every confidence;
the results are always good, and the trouble small
compared with those incurred with other solutions.

Quality of the Solution.—As I have before stated,
different platers employ solutions differing widely
in the composition.   This arises in great part from
their work being of different kinds, or from their
manipulatory skill being good or bad.   Some
platers employ a solution as poor in silver as half
an ounce per gallon, while others use one as rich
as four or five ounces to a like volume of solution.
Different factories employ different modes of work-
ing, and such great discrepancies would lead even
amateurs to infer that the limits within which
successful work can be turned out are very far
apart.   This is true to a certain extent, for by
altering the battery power and anode surface to the
liquid, it is possible to plate such a metal as copper
with either of the above strengths of solution.   For
ordinary work, however, the proportion I have laid
down (two and a half ounces to the gallon) should
be adhered to as nearly as possible.   The amount
will probably vary as the work is carried on, but

every care is necessary to employ such 'proportion
of free cyanide as will assist the anode plate to .
throw off *just as much silver as is laid upon the
articles.* This is really the secret of good working
and keeping a solution, when once made, in good
order for years.

Free cyanide is a point to be looked to constantly.
The proportion of free cyanide in a good solution
should be as nearly as possible *equal to half the
weight of the silver.* If less than this is employed
the anode will not dissolve with sufficient rapidity
to supply the metal laid upon the goods. If more
is present, the anode will dissolve too quickly, and
there is a risk of the silver being dissolved off the
goods nearly as quickly as laid. (See *Management
of Solutions.*)

"*Bright*" *Silver Plating.*—This is a process em-
ployed in the plating factory by which a brilliant
appearance or finish is given to the goods after they
have been plated in the ordinary way. It saves a
great deal of trouble, because the surface is finished
as if it had been burnished. It is questionable
whether the solution is of use to the amateur, as
it does not appear to work well in very small
volumes.

To make this solution, place a quart of ordinary
plating solution in a special bottle, add to it four
ounces of liquor ammonia, two of ether, and four
of bisulphide of carbon. Shake well, and stir in
an ounce or two of this mixture to every twenty
gallons of plating liquid it is required to "brighten,"

about twice a day. This is done as the bath is work-
ing. All the bisulphide of carbon mixture must
not be added at once—this would spoil the whole
solution. As the 'plating goes on, a little should
be stirred in after the day's work, as mentioned.
It is of the greatest importance *to·use as little as
possible* of this destructiye bisulphide of carbon,
as it is very apt to ruin the solution altogether.
And no solution should be thus " brightened "
that it is required to plate ordinarily•with again,
as it will be unfit for that purpose. If the
articles become spotted or streaked with a bad
brown colour, it indicates that *too much* brighten-
ing liquid has been used, and the best plan probably
in this case is to work upon a silver cathode until
the excess is worked off. Bisulphide of carbon by
itself will produce the effect, but the mixture given
will be found more satisfactory.

A stronger current than usual must be passed
in a brightening solution. The action is slower
than in ordinary solutions. As a rule the effect is
first apparent at the lower end of the article, and
sometimes as long as twenty minutes passes before
the whole surface is bright, but the time greatly
depends upon the battery power. If a valuable
article is being spoiled by becoming brown instead
of bright, remove it and dip for a few seconds in
nitric acid, and try again. But as a rule too much
bisulphide of carbon spoils the solution for several
days. It is, in fact, an exceedingly risky process in
the hands of the inexperienced,• and this is the

chief reason why amateurs seldom succeed with it.
For small volumes, such as a gallon of solution, a
few drops of the brightening mixture will be
enough every evening, with stirring. It is always
necessary to remove all traces of the brightening
liquid after removal from the solution by rinsing
in boiling water. If this is not done the surface
will discolour. The skin thus given to plated
goods is very hard, because the rate of deposition
is slow. M: Plante's method of brightening is to
add sulphide, of silver to the solution instead of
bisulphide of carbon.

Management of Solutions.—The standard cyanide
solutions are liable to continual change. They are
apt to change in strength, through an insufficiency
of cyanide or unsuitable battery power, and the free
cyanide is liable to change in quantity from the
latter cause. Experience shows that a new solution
does not deposit silver so freely as one in constant
use. Indeed, difficulty is often experienced in
working a new solution, which objection vanishes
gradually as the work goes on. If care is taken
the solution will improve until it has been at work
daily for a year or two, when contamination with
base metals and other impurities generally spoil it.

The *anode* should be pure silver sheet, with an
area as great as that of the articles to be plated,
and connected to the copper pole of the battery. It
should show when working a grey surface, and
when the current is stopped a white surface. If the
anode is white while the work is going on, there

is too little free cyanide. Should the anode show
a brown or discoloured surface, there is too little
cyanide in the free state, and more should be stirred
in. If the anode is too large in proportion to the
articles being plated, too much silver will be dis-
solved into the solution, which evil will be aggra-
vated by too large a proportion of free cyanide; and
if, on the other hand, the anode is much smaller, too
little metal will be dissolved, and the solution
robbed of its stock. This will be aggravated by too
little cyanide. Impurities are usually dust, acci-
dental dirt, impurities from the anode, metals
corroded while being plated—this latter is usually
caused by too weak a current, and the work being
done too slowly.

These impurities rise in the solution as soon as
any disturbance is caused, settle upon the surfaces
being plated, and spoil the work. They produce
vertical streaks, ending in a round mark. Filtra-
tion should be resorted to when the solution gathers
impurities. To continuously produce good plating,
the solution should be well stirred up at the close
of the day's work, and motion should be given to
the articles while being deposited upon. Indeed,
the latter precaution is imperative in most solutions
for a reason which I shall explain. At the anode
surface there is being continually formed the double
cyanide of silver and potassium. This salt going into
solution, is heavier than the liquid, and descends;
while the cyanide of potassium set free at the
surface of the articles by the silver leaving it, is

light, and tends to ascend. 'The result is, that, if mixing is neglected, the articles are apt to be well plated only at their lower extremities, while the anode will probably be cut nearly through at the surface of the liquid, through the excess of free cyanide near the surface. It will thus be obvious that strong solutions require more frequent attention than those poor in silver, because the heavy silver salt has a constant tendency to descend. The solution should have added to it water to make up for loss by evaporation and other causes, and it is best to add any necessary free cyanide with this water. Never stir up the solution before commencing to work, because the impurities always present rise and take a long time to settle. If the deposition goes on very slowly, it will generally be caused by too small a proportion of silver. This may be added in the form of cyanide, but it is much better to give more anode surface, and dissolve the required metal in by these means. Poverty of metal is often indicated by the deposited silver having a grey or dead appearance, and the work going on sluggishly—that is, if the anode indicates that there is a sufficiency of free cyanide. Free cyanide is lost slowly by the carbonic acid of the air acting upon it and converting it into carbonate of potash.

If the articles being plated are bad in colour, of a dirty grey or brown, it indicates, in all probability, that the current is too strong. This is best remedied by simply placing the anode farther away

from the articles.   It 'is also well to note that this
may be caused by an excessively weak current,
and a deficiency of free cyanide.   This appearance,
however, is generally found upon such metals as
tin, lead, Britannia metal, and white alloys' gene-
rally, and' seldom upon copper or brass. .

A test for the free cyanide will be useful.   I select
one of many practised.   Put in a tall glass vessel
twelve ounces of the solution to be tested ; make a
solution of half an ounce of crystallized silver nitrate
in five ounces of water, and add it to the solution
in the glass with stirring.   Add very slowly the
latter half.   A precipitate will form ; if it dissolves
quickly, there is a deficiency of silver or too much
free cyanide.   If it will not all dissolve after stir-
ring, there is too much silver or too little free
cyanide.   As a matter of course there must be too
much cyanide when there is a deficiency of silver
for it is in reference to the silver that the free
cyanide must be viewed.

Strong solutions are always more difficult to
manage in hot weather than weak ones, especially
if they contain much free cyanide.   Such solutions
and at such temperatures, must be kept in almos
constant motion, by the goods being moved to
and fro. This is generally done in factories by a
mechanical contrivance, variously made, by which
motion is given to the articles from the machinery
Sometimes the frame which suspends the plating
rods is mounted upon four small wheels, which
ride upon rails fastened to the top edge of the vat

and other more simple contrivances are in use, but they are to a great extent unnecessary if attention is paid to stirring up and well mixing the solution every evening after the day's work is done. If this is regularly done, and the solution is still found to act more upon some parts of the articles than upon others, the fault must be in the solution, which is too strong. Solutions that are too dense may be quickly brought down by the addition of water only.

Test for Density of Solution.—The operator should be provided with a *hydrometer*, by which the specific gravity of any solution may be quickly ascertained. The specific gravity of the solution may vary. It should not, however, get below 1·042, or above 1·114. It is convenient to take a reading of the specific gravity when the solution is found to be working well, and to keep it as near to this as possible; or a little over, on account of the accumulation of foreign matter. Such tests should always be taken in the evening, after stirring up.

These directions all point to one conclusion, which is that when we have obtained a good working solution, every endeavour should be made to *keep it so*, and to carefully avoid anything which might chance to alter its constitution; to avoid the accidental contamination of it by foreign or base metals, or by accident, or by efforts to improve it, which are not indicated plainly in the preceding remarks; above all, avoid the use of bisulphide of carbon if possible, and *never attempt to " brighten " a solution intended thereafter for standard silvering.*

If the anode rapidly disappears, a test should be
taken of the amount of silver being laid. Thus,
by weighing the anode and the goods before
plating, and again after plating, it is easy to ascer-
tain whether or not too much or too little has been
dissolved off the anode.   The diminution of weight
from the anode should correspond closely with the
increase of weight in the goods.   If the anode has
lost much more metal than the goods have gained,
there is too large a percentage of free cyanide, and
if the reverse, there is a deficiency of free cyanide.
To a certain extent the solution will right itself, or
correct its own fault, in the first case, if some water
is added to keep the specific gravity down as the
metal is being dissolved.   This, of course, results
in the solution being augmented in volume.   Strong
solutions require more stirring and general care
than weak ones, and a strong solution will be
made weaker by exposing to it less anode surface.
Some platers add liquid ammonia to the solution
when the silver is of a bad colour, or too yellow,
but it should be sparingly employed, and never
used unless the solution is in good order otherwise.
Always correct ordinary faults before trying the
addition of foreign substances to the solution.

Time required in Electro-plating.—The time re-
quired to plate ordinary goods varies considerably
in different solutions and with great or small
battery power.   It is also dependent upon the
thickness of deposit required.   A coating as thick
as thin writing-paper (one ounce per square foot) is

considered excellent work, and this can generally be laid in about ten hours, half this thickness in half the time, and so on—this is with one large cell.

Battery Power required—As a rule, one cell will be sufficient in ordinary plating, and of whatever form it is, its plates must have an area about equal to that of the immersed anode. The area of zinc in solution may be regulated to the work doing. If the articles present much irregularity of surface, especially indentations or deep under-cutting, the distance between the anode and cathode must be greater than usual, and in such cases it is generally wise to employ two cells, so that the extra resistance may be overcome. (See *Batteries*.)

Cost of Silver-plating.—This will depend in a great degree upon the amount of work done—or the scale of operations. Including silver and working expenses, silver can be laid upon all ordinary goods at about 8s. per ounce—or foot of surface. This is for really good work, and the figure will vary considerably in different places. If the working expenses are low, they may be laid down as a fourth of the cost of silver deposited. Inferior goods can be silvered at an exceedingly cheap rate. By the simple-immersion process, which is peculiarly applicable to small articles, buttons, nails, hooks and eyes, and suspension chains can be silvered at about 3d. a pound. But the silver is a mere covering. By the battery process such goods as teapots, sugar-basins, and silvered flagons can be properly plated, labour included, at about

6s., while a dozen of dinner forks can be properly plated for 4s.

But it is always a difficult matter to give exact figures, as different platers require different profits: These figures refer to the work as done by the plater to the " trade "—the " trade " being the manufacturer of the goods, who generally sends them to the professional plater for treatment. There is unfortunately no check upon the English plater, nor do the public know what they get in purchasing electro-plated goods. Such a state of things is not allowed in France, where every article is stamped to indicate the quality of the plating. This is done by an officer appointed by the government, the articles being weighed, before and after plating, in his presence.

" *Oxidized*" *Silver.*—This effect is produced by laying upon the silver a film of sulphide of silver, or it may be done by a film of platinum, which is not the cheapest but the best way. The appearance may be as light as a steel grey, and from this, through all the shades, down to nearly black. Make a solution of perchloride of platinum, and brush on while hot. It is also better to heat the article. If the solution is weak, and the temperature low, a steel grey will be given, and according to the strength of solution and its temperature will the colour vary to nearly black. The deepest effect is produced with a saturated solution at a temperature of boiling water. It may be necessary to remove a white appearance outside the coating

by dipping in weak liquid ammonia. The appearance of frosted silver may be given to silver articles by depositing upon them a mere blush of copper from a sulphate of copper solution, and over this an exceedingly thin layer of silver. The articles, as they come from the solution in ordinary plating, have a very pleasing dead white or " mat " appearance, which may or may not be left upon them.

A Blue-black Effect.—This is produced by treating with a solution of potassium sulphide (liver of sulphur of the shops). The solution must be hot, and should be freshly prepared.

A Pink Effect.—A solution (saturated and hot) of chloride of copper will produce this. The article should be afterwards well washed and dried in sawdust. (Fearn.)

"Stopping-off" Composition.—When it is required to protect any portion of an article from the plating, or upon which any of the above effects are produced, good quick-drying copal varnish may be used in plating, and in ·hot solutions the same with the addition of various substances, such as peroxide of iron (jewellers' rouge) or peroxide of manganese. The best varnish, however, for use in hot solutions is composed of plumbers' resin, 10 parts; yellow bees'-wax, 6 parts; fine sealing-wax, 4 parts; polishing rouge, 3 parts. (Gore.)

"Finishing" Plated Goods.—If the colour is not good, dip in a weak solution of cyanide of potassium, rinse in boiling water, and dry in boxwood sawdust. If the general dead-white or " mat " ap-

pearance is to be left upon the goods, dip at once in boiling water, and dry in boxwood sawdust. If the articles have been plated in the ordinary solution, and it is intended to have them bright, polished, or burnished, dip in boiling water, dry and scratch-brush them with the ordinary brush. Hard hair-brushes may be used for this purpose in the hand. Bath-brick may be used with water, whiting, rotten-stone, and finishing with rouge. The burnishing is done with steel or agate burnishers, generally of an oval shape, and the strokes must all be in one direction. Stale beer, or even soap and water, may be used to make the burnisher work well. It will spoil the work to cross the strokes, and all ribs must be burnished down. Finishing is, in fact, almost a special trade, and in electro-plating works finishers do nothing else. (See *Preparation.*)

Analysis of Solutions.—I add to the foregoing the following particulars of new methods by which the composition of a solution may be known. A known measure of the sample is largely diluted with water and raised to boiling. Sulphuretted hydrogen (see *Chemicals*) is then passed into it, or sulphide of ammonium gradually added. The silver goes down as a black sulphide, which filters and washes well, and, according to the books, is free from copper and zinc. This, however, is not the case in every instance, as any zinc which may be present is sure to be thrown down. On this account I never weigh the precipitate, but treat it

further. The washed sulphide of silver is rinsed
off the filter into a flask or beaker, and treated with
. excess of bromine water, which converts it rapidly
and completely into silver bromide. If any sulphur
' appear to have separated, a drop of bromine should
be added to the residue, so as to insure complete
oxidation. Now add boiling water and wash the
silver bromide, dry, fuse, and weigh it. This will
indicate the percentage of silver, the most impor-
tant point. The cyanide may be found as before
directed for free cyanide.

Recovery of Silver from Spoilt or Old Solutions.—
The wet way is generally to precipitate the silver
as chloride by the addition of hydrochloric acid,
washing and drying the precipitate, and fusing
with carbonate of potassium and saltpetre. Great
care is necessary in precipitating thus. Hydro-
cyanic acid gas is given off, which must be strictly
avoided, and for this reason the operation should
be performed out of doors. It is better to evaporate
the solution to dryness and to fuse the residue,
washing the fused mass free of the potassium
cyanide. The first operation must be conducted in
a very tall vessel, because very violent action re-
sults from the addition of hydrochloric acid. The
process recommended by Mr. Sprague is as fol-
lows :—Place the solution in a large flask fitted
with a safety funnel and delivery tube, and connect
to this by an india-rubber pipe a wide glass tube,
which place in another vessel, so that its end dips
half an inch or so under a solution of nitrate of

silver.   Now add sulphuric acid gradually by the
safety funnel, allowing the effervescence to subside,
and shake the flask occasionally; continue adding
acid as long as it produces any fresh precipitate.
Then, by means of a sand-bath, heat the flask and
keep the solution boiling as long as a precipitate
continues to form in the other vessel. This pre-
cipitate is pure cyanide of silver, and only needs
dissolving in cyanide of potassium to form a fresh
solution.   The precipitate in the flask is also
cyanide of silver, but not pure, though sufficiently
so for use in most cases; if it is preferred it can be
reduced by zinc and hydrochloric acid, or dried
and fused.   This process saves the cyanide of
potassium otherwise required to precipitate the
silver. The author suggests, as advanced by Mr.
Sprague, that this process might also be useful in
preparing solutions from the beginning, as in-
cluded in the directions before given, by placing a
solution of cyanide of potassium in the flask, and
distilling over the hydrocyanic acid into a solution
of nitrate of silver.

It will be observed that, as cyanide of potassium
plays so important a part in practical silver-plating,
a great many of the directions I have given are
subject to modification as to the weight of this salt
used.   Although the subject scarcely belongs to
this section of my little work, but to that devoted
to necessary remarks upon the required chemicals,
a caution not to accept the chemist's computation
of the percentage of actual cyanide in the salt is '

quite necessary. This salt is commonly sold of as poor a quality as 25 per cent., and unless precaution is taken mere rubbish is easily mistaken for good cyanide. It should never be under 45 or 50 per cent. (See *Chemicals.*)

CHAPTER VI.

Deposition of Nickel.

Its Salts.—The generally used salts of nickel are its sulphate, nitrate, chloride, oxide, and carbonate. Commercial salts, the oxalate and sulphate.

Sulphate of Nickel.—This salt is most commonly prepared by slowly heating oxide or nitrate of nickel in plenty of diluted sulphuric acid until it is dissolved, and then evaporating the acid by heat nearly to dryness, and setting aside to cool and crystallize. Sulphate of nickel is easily soluble in water. Its price varies with that of nickel, but it may be stated at about 2s. per oz. in small quantities.

Nitrate of Nickel.—Dissolve metallic nickel or its oxide in diluted nitric acid, gently heating. When completely dissolved, evaporate off the acid and set aside to crystallize. It is a green salt.

Chloride of 'Nickel.—Make a solution of nickel nitrate, add a large percentage of hydrochloric acid, and evaporate, or simply dissolve the metallic nickel in the acid and evaporate. Chloride of nickel is also a green salt.

Oxide of Nickel.—This may be produced by making a solution of the sulphate or nitrate, and stirring in a strong solution of caustic potash or soda. A precipitate will fall, which is the oxide, a black substance. Or the same salt may be made by heating to redness in a crucible the nitrate of nickel.

Carbonate of Nickel.—Carbonate of soda is generally used to produce this; by adding its solution to one of any salt of nickel a precipitate is thrown down, which is carbonate of nickel, a greenish powder.

Metallic Nickel is generally very impure. It contains a large percentage of silicon and some carbon, so that on dissolving it in acids a black sediment is thrown down, from which the liquid portion must be filtered if clean salts of nickel are required. It also contains a little copper. Nickel is readily obtainable commercially, but it is usually in the form of grains, as reduced by the common process. The production of nickel in slabs, for anodes and other purposes, has become an important industry. Much difficulty is frequently experienced by depositors of nickel in the small way on account of the anode required. A nickel anode is absolutely necessary in working the best solutions; they will not work steadily with a platinum plate, as is frequently supposed, even although the lost metal should be replaced regularly. A contrivance for utilising grain nickel as an anode, consisting of a flat case of carbon plates pierced with holes,

has been patented in America, but a flat case of
platinum wire gauze in the front, and carbon or slate
at back and sides, will be found better, and more
easily used. Nickel in thick plate for anodes is,
procurable on the large scale; it should be as pure
as possible.

Nickel is not very easily deposited, especially by
the simple-immersion process. Mène employs the
method of depositing it upon iron, steel, copper,
brass, and lead by contact with another metal in
the solution. The metal employed is usually zinc,
of which a strip is tied loosely to the article on
immersion in the solution. Chloride of zinc, in
boiling neutral solution with fragments of nickel
present, is the mixture employed. If the solution
is allowed to become acid, the deposited metal will
have a bad and dull appearance, which is not
readily worked off by the scratch-brush.

Another solution for the deposition of nickel by
contact with zinc is made by making a saturated
solution of zinc chloride in a copper pan, adding to
this twice its bulk of water, boiling for a few
minutes, and redissolving any precipitate which
may form by stirring in a few drops of hydrochloric
acid. Some fragments of zinc are then thrown into
the pan, which cause zinc to be thrown upon the
vessel as an adhesive deposit. Sulphate or chloride
of nickel is then stirred in until the mixture is quite
green, when the solution is ready for use. It is
used boiling, and the coating will take about twenty
minutes. If a thick coating is required the articles

are taken out, scratch-brushed, cleaned (see *Preparation*), and re-immersed for twenty minutes. All the common metals are coated, but they must have tied to them strips of zinc as before.

A great objection to the use of simple-immersion solutions for nickeling lies in the fact that as soon as the metal is withdrawn in part, a quantity of acid is set free, which renders the working of the solution nearly impossible, except with great skill. Change is continually occurring in a solution being robbed of its metal. For small operations it is even better to work the last given solution with the battery, employing a platinum anode, than to use the zinc-contact method, because the work is done more quickly, and the adhesion has every chance to be better.

Solutions for Nickel Deposition by the Battery Process.—It would appear from extensive experience that the most easily managed solutions are those made up from a double salt of nickel and some alkali. The double sulphate or chloride of nickel and ammonium or potassium may be so used with every prospect of good work. More than one patent has been taken out for the commercial working of these salts. The first appears to have been that of Dr. Adams (1869), and very lately Mr. Unwin, of Sheffield, has secured letters patent for a solution of his, modified and improved from the original mixture of Dr. Adams. The use of the salts had been known to scientific men as early as 1855, when Mr. Gore, F.R.S., deposited the metal

from them, but the experiments were upon a small scale, at that time, and only received their practically useful development at the hands of every-day workers in the art. Particulars of the best practical methods follow.

Where cheapness is not a consideration, cyanide of nickel dissolved in cyanide of potassium solution affords the best liquid from which to deposit nickel, but its working has not received much attention. The most useful solution would appear to be that of the double sulphate of nickel and ammonia, dissolved in water to saturation, and then diluted with water to reduce the density sufficiently for working. The double salt is procurable commercially at prices varying with the price of nickel itself. Half a pound of the double salt to the gallon will form a good solution, and $\frac{3}{4}$ lb. will be found even better, with less battery power.

Particulars for the manufacture of the double salt will be found useful. Put in a deep earthenware vessel three pints of strong nitric acid, one part of strong sulphuric acid, and four parts of water— by measure. The mixture must be made slowly and with care. To each gallon add two pounds of grain nickel, and heat the vessel by placing in another of boiling water; avoid the fumes, and check any violent action by the addition of a little cold water. When it is observed that all the nickel is dissolved, add more until the acid is satisfied. As soon as the solution gives over fuming, or is found to be heavy and thick, add a fourth of its

bulk of hot water, then boil the whole, and filter
out clearly. This is a strong solution of the nickel
sulphate. Prepare next a saturated solution of
sulphate of ammonia, by dissolving in hot water—
nearly four pounds to the gallon. Allow it to cool.
To obtain the double sulphate, add the ammonia
solution to the nickel one, with constant stirring,
until the latter loses all its colour. By this time
the ammonia sulphate will have combined with the
nickel salt, and the result will be a copious precipi-
tate of the pure double salt required. Pour off
the liquid portion, and wash the salt by the
addition of more sulphate of ammonia solution
(cold).

To prepare the depositing solution, dissolve the
double salt in hot water, stirring while the water is
added until all the salt is dissolved. Then simply
dilute with water until the Twaddle hydrometer
marks nearly 7° density. Test the solution with
blue litmus-paper, and if the paper turns red, add
a little solution of ammonia, well mix, and then
test with red litmus-paper; if the colour turns to
blue add a very little sulphuric acid with much stir-
ring. It is somewhat important that the solution
should be kept slightly alkaline, although it will
work fairly well a little either way, or quite neutral,
a condition almost impossible in practical work-
ing. Some of these items form the subject of a
patent recently secured by Mr. Unwin, of Sheffield.
The solution is undoubtedly a good one for general
work. Some particulars of others follow, exhibit-

ing the fact that nickel may be deposited from a
variety of solutions.

Thus sulphate of nickel dissolved in water, with
its free acid neutralized by liquid ammonia, can be
deposited from successfully. This is Becquerel's
solution. If the liquid is worked by the zinc-con-
tact method the nickel will disappear slowly, and
to refresh the liquid it is best to stir in oxide of
nickel in sufficient quantity. If the solution is
worked by the battery current, while the anode is
properly dissolving there will be no need of fresh
metal, but the free acid must be neutralized by
adding ammonia, and it is better to have the bath
slightly alkaline than acid. Becquerel states
that the deposits from this solution are brilliantly
white.

Much has been said about the advisability of
excluding from nickel solutions the salts of potas-
sium and sodium. It is clear that such solutions
will not work well if soda is present, but the same
cannot be said of potash, as it is known that
Becquerel deposited good nickel from the double
sulphate of potassium and nickel. There can be
no doubt, also, that a very good solution might be
worked composed of cyanide of nickel in solution
of potassium cyanide. A very easily made solution,
and one from which good nickel may be obtained
by the battery process, is made by dissolving dry
crystals of protosulphate of nickel in liquid ammonia
of good quality. Place the crystals—say for three
quarts of solution—in the depositing vessel, and

stir in the ammónia until the whole is dissolved. Half a pound of nickel sulphate will be sufficient; the liquid will be of a dark blue colour.

Another solution is máde up by stirring half a pint of liquid ammonia with a gallon of water, then adding, with more stirring, ¾ lb. of nickel sulphate, and finally adding three pints more of liquid ammonia. This solution when used should be heated, but not to a boiling temperature. It is useful for the purposes of amateurs, as it works well with a 'platinum anode; but nickel sulphate must, of course, be added as the work goes on, and if the liquid becomes acid it must be rendered neutral or slightly alkaline by adding ammonia.

Roseleur mentions a solution which I am inclined to regard with distrust. It is made by dissolving the nitrate of nickel in its own weight of liquid ammonia, and then stirring into the liquid as much as twenty times its volume of bisulphite of soda in saturated solution (water). It is stated that the deposit is of a dull grey colour. I have not tried the mixture, but should imagine it to be difficult to manage. Another solution of a better kind is made by making a saturated solution of chloride of nickel, and precipitating the metal by stirring in a strong solution of ferro-cyanide of potassium (yellow prussiate of potash). Wash the precipitate, and dissolve it by stirring into it a solution of cyanide of potassium. It may be diluted, but will work in the condition described. Several solutions employing caustic potash have been tried.

Their distinguishing characteristic would appear to
be the ability to deposit the metal in a white and
brilliant coating, which is very liable to strip, and
apt to contain gas. Such a solution may be made
by dissolving a pound of nickel sulphate in two
gallons of water containing half a pound of tartaric
acid, and then stirring in an ounce of caustic potash.

Anodes and Anode Surfaces.—Nickel anodes are
usually made very thick, as cast from a large mass
of metal. Such plates are only suited to the
purposes of professional platers. The amateur
may work a small bulk of solution with a pla-
tinum anode, made of thin platinum foil; but in
this case the solution must be kept in metal by
adding the sulphate as it is withdrawn, and a con-
stant watch must be kept upon the state of the
solution. The plan may be good enough for
occasional plating with nickel, but is quite unsuited
for regular work. The anode surface in a nickel
bath must be *larger* than that of the article being
plated, and it is usual in plating factories to expose
as much as six to nine square inches per gallon.
To cast nickel into plates or ingots for making into
anodes, place the grain or cube nickel in a steel
melting-pot, add a little borax as flux, and fire
the mass as is usual with other metals. Nickel
being somewhat difficult to melt, a good plan is to
add to the mass in the pot a little grain tin, which
renders its liquefaction comparatively easy, and is
no disadvantage in the plating-vat. . Anodes are
always better after working for some time. It is

difficult to obtain nickel anodes in a reasonable
state of purity. I observe that important improve-
ments are being made in the working of the metal,
which may result in the elimination of common
impurities. As now used it is very much like cast
iron, and therefore cannot be easily worked. It is
usually cast into plates nearly an inch thick, and
about twelve inches square. In the process of
casting, a pair of hooks should be fixed into one
edge for convenience of support in the liquid.
When the grain nickel, in a platinum or porcelain
basket with a platinum or carbon back, is used, a
great deal of impurity is separated in the action, so
that the lower layers are excluded from the action
altogether. Such makeshifts should be shaken up
often, and the dirt allowed to fall down.

Working the Solution.—It is important that the
articles should be well cleaned, and it is found that
nickel will deposit on well-cleaned iron and steel
as quickly as upon copper. Nickel depositing is
somewhat difficult to beginners, and the obstacles
met with are not in the choice of the solution, but
in the working of it. The solution must be kept
either neutral or slightly alkaline, otherwise it will
cause a great deal of trouble. The battery power
to employ will depend upon the scale of operations.
For "striking" the first deposit two or more are
usually employed, capable of exerting an electro-
motive force of from 3 to 5 volts. The size of the cell
should be proportionate to the surface of the articles
exposed. For the purposes of the general amateur.

with a gallon or so of solution, a pair of ordinary quart Bunsen cells will be enough for the main deposit, and three cells to give the first coating. The acids in those cells may be somewhat weak. For larger operations two cells will be sufficient in, starting the coating, and one to finish. The factory cell is usually composed of about eight zinc and carbon plates, fixed to a frame after the Smee model, and fitted so that the whole may be dropped into or raised from the exciting liquid to any extent required by the work being done. The exciting liquid is generally very dilute sulphuric acid, and the zinc plates are, of course, amalgamated to prevent waste. In large operations the battery has been quite superseded by the dynano machine, regarding the use of which see Chapter IX.

Nickel is different from most of the metals in electro-deposition. A good deal of power has to be used—so much that gas is often given off copiously in the process, particularly at the beginning of operations. To prevent the absorption of gas by the deposit, the solution should be strong, and as little gas as possible should be evolved on account of this tendency. When the work may be done very slowly, one cell only will be sufficient, even in small operations. Nickel that has been deposited slowly is more likely to be tough and good, with a good surface, but too much time must not be allowed at the commencement, otherwise the coating may quite fail to come, or it

may be very apt to split from the surface. Thick
deposits are more difficult to lay than thin ones,
owing to their tendency to absorb gas. The articles
should be kept in motion to insure regularity of
deposit, and prevent the formation of blotches and
streaks on the surface. If the anode is so impure
as to show upon its surface a coating of blackish
matter which will not fall off as the greater part
of such impurities do, it must be brushed away in
the liquid, but not while the current is passing. It
is most convenient to stir up the solution and shake
or clean the anode every evening. *A good deposit of
nickel when deposited by battery is of a dull colour,*
and not of a white or brilliant surface.

Deposits of nickel having a brilliant appearance
on leaving the solution will seldom stand. They
are very apt to strip. When powerful currents are
used, with a weak solution the deposit is com-
monly pure white, and needs only to be polished.
" Polishing lime " from Yorkshire is usually em-
ployed on the leather polishing " bobs " or wheels.
To insure the deposition of a good coat of nickel,
the battery power must be uniform. The anode
should be left in the solution overnight; this will
tend to keep the bath in order. Regular and
smooth deposits are only obtained upon smooth
and very clean surfaces. There is no real difficulty
in the regular and successful deposition of nickel
after the operator has had a little practice.

When a nickel solution has been in use for some
time, it will stand in need of purification. This

may be done in two or three ways. I have found the use of ammonia alum to be beneficial. Dissolve an ounce of the alum (for each gallon of solution) in a little hot water. Stir in this to the bath, until a perfect admixture is obtained. Test the liquid with red litmus-paper. If it turns the paper blue, make no addition, but if it fails to do so, stir in a quantity of ammonia until the desired effect is obtained, exhibiting a slightly alkaline tendency. Allow any precipitate to settle slowly, and strain or syphon off the clear liquid, returning it to the vat when the latter has been properly cleaned out.

A Modern Nickel-plating Room contains, as the source of electricity, either a dynamo - electric machine, driven by steam (see Dynano Machine, p. 80), or a pair of large stoneware jars as cells, containing as much as ten gallons of liquid each, fitted each with twelve zinc and carbon plates arranged alternately in frames. The nickeling vat is a well-bolted wooden tank, of such a size as will suit the articles to be done, and containing, usually, sixty gallons of the nickel solution. It is lined throughout with best asphalt, or sheet lead thinly lined with wood. Around its outer edge is a raised rail of brass, resting on which, and extending over the solution, is a brass rod from which hang the articles to be nickeled. Another brass rail is fixed lower down on the inner edge, and from a rod placed upon this is supported the nickel anode. These two rails are joined by wire to the battery, the anode one to the carbon, and the article one to

the zinc. There are also a pair of vessels containing alkali. cleaning solution, and acid' vessel, soft. water, scratch-brush lathe, and a polishing or buffing lathe.

With such arrangements the nickel may be deposited cheaply; and at a considerable profit. The bath will give little trouble, and will work continuously as long as proper attention is given to it.

Uses. of Nickel Plating.—Although nickel is so much less in price than silver, its cost as deposited is not correspondingly less. Of late the extension of nickel-plating operations has been so great that the metal has become the common protection against corrosion upon a numerous class of goods. The work is done at a surprisingly cheap rate. It is therefore in extensive demand for bicycles and other work of that class.

Peculiarities of Nickel.—Electro-deposited nickel is very hard, so that it is very lasting. It has a blue tint, and takes a very brilliant polish, which, unlike silver, it does not readily lose. It is not affected to any great extent by the sulphuretted hydrogen given off by burning coal gas, and is therefore well suited for use as a covering to all kinds of shop fittings, particularly bar pumps, scales and weights, door plates, fire-irons, polished fenders, carriage fittings, surgical instruments, and innumerable other purposes. It must not, however, be used as a lining for cooking vessels, because it is very readily affected by acid substances.

Recovery of Nickel from Old Solutions.—I am not aware of any particulars similar to the following having appeared in any previous work concerning the recovery of nickel from an old solution. I give a method which I have employed myself, and which I have reason to believe might be improved upon. I take advantage of the curious property of sulphate of ammonia in precipitating the double sulphate of nickel and ammonia from the solution. Make up a saturated solution of ammonia sulphate in warm water, and add to the old solution with constant stirring. No effect will at first be observed, but in a few minutes a deposit of the double sulphate will begin to fall. The precipitated salt is beautifully pure, and may be used direct in making a new solution. The precipitation should be continued until the liquid is colourless.

CHAPTER VII.

Deposition of Gold.

Its Salts.—The useful salts of gold are its oxide, iodide, bromide, sulphite, hyposulphite, single and double cyanides, and terchloride, which is by far the most generally useful for the preparation of the others as applicable to the purposes of gold-plating.

Terchloride of Gold.—This salt is, like the nitrate of silver, the most common, and that which results from the ordinary dissolution of gold. The usual acids will not dissolve gold. For this purpose there is employed a mixture called aqua-regia— one part of nitric acid, and three of hydrochloric acid. To dissolve gold, for one ounce, place about four ounces of the mixture in a suitable véssel; place this in turn in hot water, so that the solution within may be warmed. Use, if possible, fine gold, as alloys are troublesome in the after-processes. Cut the sheet into strips, and add gradually to the mixture as it dissolves. When saturation is attained to, evaporate the solution, stirring occasionally until the bulk is small. Allow to cool slowly. If too much heat, is given to the mixture while dissolution is going on, a yellow powder is

apt to be formed, which must be dissolved by
adding a drop or two extra of acid. If the gold is
pure, the resulting salt, gold chloride, will entirely
dissolve in water. • If alloyed with silver a dense
chloride of that metal will form, which will probably.
refuse to dissolve. This chloride is, of course,
white. If any of the yellow or brown powder
before spoken of appears now, it will not dissolve
in water, but must be separated and again dissolved
in aqua-regia, which solution must again be evapo-
rated. It will be the best, if the salt is required
for almost immediate use, to dissolve it in distilled
water, of which a small quantity only will be neces-
sary. One ounce of metallic gold will produce as
much as 1 oz. 164 grs. of the yellow chloride. It
will always be found less troublesome to dissolve
the fine gold.

Cyanide of Gold.—To prepare the simple cyanide,
let the solution of chloride be diluted largely, and
the cyanide thrown down by a solution of cyanide
of potassium. The strength of this solution may
be about one ounce to the pint. It should be
added carefully, with plenty of stirring. The pre-
cipitate is a lemon-yellow powder, and is readily
soluble in cyanide of potassium. In large opera-
tions, before finishing the precipitating of cyanide,
it is best to add a little more cyanide of potassium
than at first appears to be necessary, to avoid the
risk of any of the chloride remaining in the solution.
This may redissolve a little of the cyanide, but it
may be recovered by decanting the liquid portion .

from the cyanide, and rendering it strongly acid
by the addition of sulphuric acid. A better way
than the above, when large quantities are to be
operated upon, is to neutralize the solution of gold
chloride by adding a little strong solution of caustic
potash or caustic soda, but this must not be used
too liberally.

Oxide of Gold.—This salt is obtained by treating
a solution of the chloride with calcined magnesia.
The precipitate is the oxide; it should be washed
with diluted nitric acid, and then with water only.
Plenty of the magnesia must be used, and if it is
desired, an excess of caustic potash or soda may be
employed in its stead, but the risk of loss is greater.
With the magnesia the heat must be regular and
not rise to boiling.

Sulphide of Gold.—This salt is generally prepared
by passing a stream of sulphuretted hydrogen gas
(see *Chemicals*) through a solution of the chloride
as long as any precipitate occurs. It is not often
used in electro-metallurgy. It is a dark brown
substance, in the form of powder.

Bromide of Gold.—This is seldom used. It is
usually prepared by heating the oxide in hydrobro-
mic acid, and afterwards evaporating very slowly.

Fulminate of Gold.—A dangerous substance. It
should never be prepared until it is just wanted, as
it is violently explosive, and on this account *must
not be dried,* or touched while it is dry. By adding
liquid ammonia to the oxide of gold fulminate of
gold is formed. It is more conveniently prepared

by using the chloride of gold in solution, and pre-
cipitating the fulminate from this by addition of an
ammonia salt in solution (or common liquid am-
monia). It may also be formed by adding to the
oxide solutions of ammonia, such as the chloride,
sulphate, or carbonate. This dangerous substance
is also called aurate of ammonia and ammoniuret
of gold. It is a brownish powder. After the ful-
minate is formed by ammonia, it must be washed
several times to rid it of the smell of ammonia.
The greatest care is necessary not to allow any
particles of it to dry upon the sides or edges of the
vessel. In filtering still greater care is necessary,
as particles of it are apt to dry upon the filters.
If any particles dry, they should be washed off—
not scraped—with a little cyanide of potassium
liquid.

Double Cyanide of Gold and Potassium.—This salt,
when required, may be prepared by dissolving the
simple cyanide of gold in a solution of cyanide of
potassium, and evaporating the solution almost to
dryness. The salt will crystallize out on cooling,
and only needs to be dissolved in water to form
the cyanide plating solution.

Gilding by Simple Immersion.—A solution suited
for cheap gilding, and applicable to large surfaces
generally, is made as follows :—Dissolve 2½ lbs.
of caustic potash, 5 oz. of pearlash (carbonate
of potassium), 2 oz. of cyanide of potassium in 5
quarts of water, in which must previously have
been dissolved ¼ oz. of gold chloride. Before using,

this solution must be heated nearly to boiling, and it is upon the temperature that the colour will depend. It is suited for the gilding of clocks, bronze figures, and gas-fittings. It may be necessary to work up the surface obtained with a brush and whiting, finishing with rouge and burnisher.

Another solution, the particulars of which are due to M. Roseleur, is composed of pyrophosphate of soda 800 parts, in 10,000 parts of water, adding eight parts of strong hydrocyanic acid. Convert ten parts by weight of gold into dry soluble chloride, dissolve it in a reserved portion of the water to which nothing has been added, and mix both solutions together, cold. When cold the solution is yellowish, but becomes dark upon heating. It is used hot. Poor cyanide, or hydrocyanic acid, will make it appear red, and more must be added until the colour disappears.

It is necessary to "quick" all the goods to be gilded in this solution in nitrate of mercury solution in the usual way. (See *Preparation.*) Motion must be given to the articles whilst being gilded. It is recommended to gild first in a nearly exhausted solution of the same kind, to lay a kind of preparatory skin; then in a slightly richer solution, and to finish in a freshly prepared one to give a good colour. A few seconds in each solution are sufficient. If it is desired to lay "green" or "white" gold, add to the last solution a solution of nitrate of mercury, drop by drop, with stirring, until the desired colour is apparent.

It is not uncommon in factories to do a great deal of the gilding by the simple-immersion process alone. It· is possible to do this by very often "quicking" the surface in the mercury solution. First the cleaned article is "quicked," then rapidly gilded, quicked again and gilded, and so on for five or six dips. The work may be got through more rapidly than might be expected.

A very good solution for simple immersion is made by dissolving one part of gold chloride in water, and adding to it, gradually, thirty-one parts of acid carbonate of potassium. Then mix the so-lution with one composed of thirty parts of acid car-bonate of potassium in two hundred parts of water. The whole must be boiled for two hours. As soon as the solution turns green, it is ready for use. It is not necessary to "quick" the surfaces of articles to be gilded in this solution, but it is advisable to do so for the best work. To gild German-silver or silver, they must be dipped with zinc strips or wires attached loosely to them.

Silver articles are perfectly gilded by the follow-ing solution, applied hot:—Dissolve an ounce of each sal-ammoniac and corrosive sublimate in three ounces of nitric acid, add some grain gold to it, and boil down to half its bulk.

To gild in different colours, various methods are in use. Thus we employ any of the solutions given, and obtain a red gold when the temperature is high. If a green gold is required the articles are immersed at a lower temperature, and a solution

of silver nitrate added drop by drop, with stirring. It is found that a very little silver in a gilding liquid will turn the deposit green and white, while .ᵢ very little copper will turn it red.

To gild "*dead*." This may be done in the simple solutions, and is more applicable to copper and brass than to most other metals. Make up a mixture of sulphuric. acid, 2 ounces; nitric acid, 2 ounces; common salt, ½ ounce, and dip the jewellery into it for a moment only, or until it presents a dead appearance—then gild in the usual way.

To " bright gild " a specific article. Let us suppose that the article is a brass watch-chain. Commence by pouring hot water into a vessel over the chain, and into this scrape a quantity of bath-brick and soap. Rub the chain briskly in the hands for a few minutes, to clean it. Next, substitute whiting for the bath-brick, and rub in the hands with soap and water until all the links are smooth. This done, wash well out in hot water to .remove the soap, and when clean, fasten a slender wire to the article, and dip in the gilding bath. The result is, perhaps, a fairly good colour at first, which may remain until we think the chain is well coated. But, as a general rule, the chain is no sooner in the liquid than it begins to change colour to a dirty, and apparently unsatisfactory yellow, which then deepens to brown, after which, as a rule, no more gold will go on. This bad colour must be worked off by rubbing in the

hands with whiting and soapy water, when a
.fine rich yellow appears; and as soon as this is
well exposed in all parts, wash off the soap. Dry
the chain in sawdust, and then bring up·its surface
by rubbing briskly in the hands with dry sawdust
only. A shake will finish the process.

These simple directions will enable amateurs.to
do such work for themselves, and any of the good
solutions may be employed. 'Articles of jewellery
which cannot be cleaned in this way should be
rubbed with a brush. For useful solutions, see
Making Solutions by the Battery Process.

Electro-Gilding.—The first necessary directions
in the art of electro-gilding are those referring to
the best solution. No solution has been found to
work so well as cyanide of gold dissolved in a
solution of potassium cyanide, or the double
cyanide of gold and potassium dissolved in water.
There are two ways by which the solution may be
made—the chemical and the battery process. The
first is suited to the larger bulks of liquid, while
the other is well adapted to the purposes of
amateurs, or those requiring only a small quantity.

I give directions by which any quantity of the
solution may be prepared, from a pint to many
gallons.

*One ounce of Gold per gallon should be present in a
good solution.* This will serve as a guide for smaller
quantities, as the gallon is 160 ounces. But, as
with other metals, the proportion may vary con-
siderably. Weigh the gold, and convert it into

solid · chloride, dissolve in water, and prepare a
solution of cyanide of potassium (1 ounce to the
pint) of half the bulk. Add the cyanide to the
chloride solution with stirring. Do this slowly,
and give time to the precipitate to subside. Pre-
serve the liquid, which is to be poured off; wash
the precipitate several times with fresh water, pre-
serving these washes. Put all the washes into
one vessel, and add sulphuric acid to throw down
any stray gold. The precipitated cyanide of gold
is now to be stirred into a small bulk of a strong
solution of potassium cyanide. There should *not*
be enough of this to dissolve all the precipitate,
and more is added, with stirring, until the pre-
cipitate is all dissolved. It will be found even
more convenient to leave the precipitated cyanide
in its vessel after washing, and to add to it slowly,
with stirring, a solution of potassium cyanide
until it is all dissolved. But in either case the
free cyanide must be added after this is done.
The amount of free cyanide should be about one-
fourth of the whole used, and after this is added,
the solution should be diluted with distilled water
so as to give about one ounce of gold to the gallon.
If the quality of the cyanide is over 50 per cent.
the proportion given will be sufficient; but if the
quality is poor, a greater quantity will be required.

The proportions of gold and potassium cyanide
to the gallon of solution vary according to the
class, quality, or kind of work to be done in it.
A fourth of an ounce of gold will be found to

work; half an ounce will afford a better deposit in
less time; and one ounce is sufficient for all ordinary
work.' The current needed for the richer solutions
is small. Rich solutions admit of the complete
art of electro-gilding being practised, and the
various shades of colour to be given to the articles;
while the weak solutions are only fitted for practically one colour of gilding. It is useless giving
proportions for cyanide, or the quantity of it necessary to redissolve the gold salt.

It is not uncommon for lazy people to simply
add the gold chloride, without conversion into the
cyanide, to the potassium cyanide liquid. If the
latter is strong enough, the chloride will be converted into cyanide, but the practice is decidedly
bad. If the gold chloride is used, a chloride of
potassium is formed in the liquid, and the presence
of this salt often prevents successful working, although everything else may be perfect. The oxide
is not quite so objectionable, and the same may
be said of the gold fulminate. But working in
this way is expensive, and the use of the fulminate
positively dangerous.

Another solution, the advantage of which is that
it may be used cold, is also in use. Place ½ oz.
of the oxide of gold in 3 quarts of water; add
1 oz. of the ferro-cyanide of potassium, and ¼ oz.
of caustic potash. Stir, and boil the solution
twenty minutes. When cool filter off, to get rid
of the iron precipitate from the ferro-cyanide. The
solution should have a fine yellow colour. Greater

power of current will be required if it is used cold, and the colour will not be so dark.

Another solution is made by dissolving 1 oz. of chloride of gold and 10 oz. of ferro-cyanide of potassium (yellow prussiate of potash) in 1 gallon of water (filtered rain or distilled). Filter the solution to rid it of the precipitated iron, and add to it a gallon of a saturated solution of prussiate of potash, then dilute the whole with 1 gallon of water. If this large proportion of water is not added, the colour of the deposit will be bad. It will stand even more water than this, and then give a beautiful deposit. All precautions should be taken to get rid of the iron in the solution. It will gild cold, but a richer colour is yielded when the temperature is raised. If the gilding appears to be covered with a skin of a bad colour, rub it with a smooth brush and some acidulated water. Brass and copper are beautifully gilded in this liquid.

Another one, based on the use of ferro-cyanide of potassium, is made by dissolving 1 oz. of dry chloride of gold and 10 oz. of ferro-cyanide of potassium in a gallon of water. The iron from the potash salt will be precipitated, and filter the solution from it. Boil the solution for an hour or two in a porcelain or glass vessel until a precipitate appears at the bottom. Filter again, and dilute with 2 gals. of water. The solution, before being diluted, should be of a fine yellow colour.

A solution in which carbonate of potash is used is made up thus :—Dissolve 1 oz. of gold chloride

in 1½ gals. of distilled water. Then stir in, slowly, a saturated solution of carbonate of potash ("pearl-ash") in distilled water until the mixture begins to be cloudy.

Making Solutions by the Battery Process.—This way is by far the most convenient when small volumes of the electro-gilding liquid only are required. It is peculiarly applicable to the wants of amateurs. Almost any of the simple-immersion solutions may be made in this way with little trouble. A current from two Smee or Daniell cells is usually sufficient to dissolve in the gold. A great advantage in this process is the certainty that there is no loss of gold, which by carelessness may result from many of the processes in the chemical section.

To make a quart of gilding solution by this means, dissolve 4 oz. of cyanide of potassium (50 per cent.) in a quart of water kept hot by a lamp or gas, or by being placed within another vessel of boiling water. Connect a piece of sheet gold to the copper of the battery, and to the zinc connect either a platinum or gold plate. Immerse both in the solution, and pass the current for an hour or two. Test occasionally, to find if sufficient gold has been dissolved in. This is done by disconnecting the plate connected to the zinc, and substituting one of clean German-silver for a minute. As soon as a suitable deposit appears upon the German-silver the solution is ready. It may be used instantly, with the same battery power and anode, by simply

connecting the articles to the zinc wire. If the colour is too dark, and the treatment with whiting will not improve it, simply lower the temperature until the desired shade is secured. If it is wished to have the colour red, add a very little chloride of copper to the solution, and if green or white gold is wanted, add a little of the solution of silver nitrate. In such work it is not of much consequence how much gold may be dissolved in the solution if the deposits obtained are good. A large percentage of gold will work faster than a weak solution, and the work will probably be done too fast for convenience. In large operations, however, it is well to weigh the anode before and after the operation, so that the gold may not be allowed to exceed 1 oz. per gallon—unless for especially rapid work. In simple-immersion solutions a low percentage of gold will give a thicker deposit than a solution rich in metal. But in all simple-immersion solutions the deposit is of the most superficial character.

In the preparation of such solutions as the above, the anode should be suspended by gold wires covered with strong varnish, or, which is better, a support of platinum wire, which will not be dissolved by the liquid. If the anode is large enough to allow its end to lie above the surface, such supports will be unnecessary, but care must be taken to shift the anode occasionally up and down, because it is liable to be corroded and cut through at the surface of the liquid. In such solutions the process

of gilding is rapid and simple. Care must be taken to. keep the solution at about the same specific gravity—that is, to prevent its becoming too dense, by adding water every evening, to make up for that evaporated off in the process. With simple-immersion solutions care must be taken to both add water and gold—chloride in solution will generally be found to fulfil both conditions.

Cold-Gilding Solutions.—Most of the foregoing solutions are used hot, and are suited to the better class of work. But a great deal of gilding is done on a large scale in cold solutions. It is usual, however, to deposit a mere film of copper upon the goods just before gilding, both to insure good contact, and to improve or darken the colour of the gold deposit. The articles usually treated are large, such as clock cases, "fine" goods in fenders and fire-irons, bronzes, and large chandeliers. Having fixed upon the volume of liquid likely to be required, it is well to make up nearly twice as much, because such solutions work much better in large volumes than in small quantities.

Dissolve 2 lbs. cyanide of potassium (50 per cent.) in 4 gals. of water. Dissolve 5 oz. of solid gold chloride in 1 gal. of water. Mix the solutions, and filter if any sediment is seen. Boil the liquid for fifteen minutes before using. When it gets exhausted, add solid chloride of gold and a little cyanide of potassium in water. But the directions applicable to other solutions may be made use of in working this. It will, however, be unnecessary

to allow a daily addition of water, the evaporation
being so insignificant.

Another cold-gilding solution is made thus :—
Dissolve 2 lbs. of cyanide of potassium (50 per
cent.) in 5 gals. of water. Convert 4 oz. of gold
into the solid chloride, dissolve it in water,
and stir in 2 quarts of liquid ammonia. The
usual precipitate of fulminate of gold will be
thrown down. Wash the fulminate by filtration,
using every precaution not to use any hard sub-
stance or article to remove it from filters or vessels.
Wash the fulminate into the vessel in which it is
intended the solution is to be, and add the potassium
cyanide solution. The fulminate of gold will dis-
solve quickly, and when completely invisible stir
the liquid, and boil for nearly an hour to get rid of
the excess of ammonia. To refresh this solution in
gold, the chloride must be converted into the ful-
minate. Dissolve this with a solution of potassium
cyanide, and add the liquid occasionally, little by
little, as it is required—too much care cannot be
exercised in the use of this highly explosive sub-
stance. So long as it is kept wet, and quite free
from violent friction, it is safe enough.

The colour of the deposit from both these solu-
tions will serve as a guide to the quantity of gold
necessary. If the colour is too pale, a little more
gold will probably darken it. But a stronger
current will often do the same, so that adding to
the current should be tried before adding gold. If
there is too much gold, and the current strong, the

deposit will be too dark; it may be red, or even brown. Too much cyanide of potassium will cause the work to go on very slowly, and the colour will be very poor, because an excess of cyanide will dissolve off the gold as fast as it goes on. If the bottom of the article receives a good deposit, and the top a poor one, it indicates that there is a slight excess of cyanide, but that the fault may be remedied by stirring, and keeping the articles in motion. A stronger current will generally counteract the effects of too much cyanide, but the addition of gold may be necessary—chloride to the first and fulminate to the latter solution.

"*Colour*" *in Electro-Gilding.*—It is of the greatest importance to possess a knowledge of the art of regulating the current and general working of hot electro-gilding liquids, so as to make the process useful in producing not only deposits of gold, but those of any desired colour.

As a general rule, it will be found best to obtain any excessive colour by *additions* to the bath, and not by attempting to work it up to this by the current or temperature. Thus, to obtain red or green gold of decided colour, it will be necessary to make additions in the shape of acetate of copper and nitrate of silver. Now, if it is not required to perpetually gild in this colour, or at least until all the added metal is worked off, the bath will be spoilt. It is always wiser, when excessive colour is required, to either make up a separate solution for that particular colour, or to make the main

bath up if the work. is always to be carried
on.

To make up a bath for *red gilding*, grind a little
of the acetate of copper (crystallized) to powder,
dissolve in water, and add to the bath, with stirring,
every evening as much as may be required. In a
new bath, where there will be no troublesome sedi-
ment to disturb, the addition may be made at any
time, and the quantity augmented if the colour is
not sufficiently deep. It must not be forgotten,
however, that gold so coloured is not so fine as a
yellow gold. Attention should be given to some of
the directions which follow, so that the battery
power and temperature may be regulated to assist
in the production of deep colour, it being important
that too many of the foreign substances are avoided
in a good bath.

To obtain *green* and *white gilding*, the addition is
a solution of the crystallized nitrate of silver. This
is added in the same way as the copper. A very
little (a few drops) will generally produce green
gilding, and a little more white.

To deposit a gold of *pink* appearance is a more
troublesome matter. The surface is first coated
yellow, then thinly red, and over this is produced
an exceedingly thin coat of silver in a silvering
solution. Such surfaces are very lasting, and
ought to be burnished.

A good cyanide-gilding solution should be of
sufficient strength to allow of its producing from a
pale and poor-looking deposit to a deep and

nearly red rich gold. For such purposes the solu-
tion may even contain as much as $1\frac{1}{2}$ oz. of gold
per gallon, but over this it is not advisable to go,
for the reason that the paler tints are not readily
obtainable. The poorer solutions will produce fairly
pleasing tints when the current is strong, and the
temperature high, but the darker shades are very
apt to have a dingy appearance, instead of that
mellow and clear surface which is the chief aim of
the practised gilder.

A *dead* gilding will be produced by the addition
of a little of the fulminate of gold in solution to
the bath immediately before gilding, or dip the
articles (brass and copper) before gilding in a
mixture of sulphuric and nitric acids.

Speaking of the solution recommended by me,
as holding 1 oz. of gold per gallon, it will pro-
duce its darkest effect when the temperature is at
boiling point, the battery power two cells of the
Smee or Daniell type, and the anode only a few
inches from the articles. Almost any desired shade
may be obtained by lowering the temperature, the
battery power, and keeping the anode and articles
further apart. The colour will, as a general rule,
be too dark on removal from the solution, but the
process of scratch-brushing will clear off the super-
ficial covering and expose a pleasing effect. *It is
necessary to produce a darker gilding than is finally
required.* If there is a difficulty in obtaining a gold
of yellow tint, the addition of some caustic soda in
solution will produce it, but of this salt very little

must be used, and then only when absolutely
required. A great deal may be done by allowing
more or less anode to dip into the solution. If a
solution is poor in metal, and it is required to
bring it up, to 1 oz. per gallon, let the anode
be much larger than the articles, and the deposition,
with adding of gold, will go on at once. If the solu-
tion is too rich to produce, with any working of
current, anode, or temperature, the gold required,
its fault may easily be corrected by allowing less
anode surface than the articles expose until the
desired effect is produced. These changes will be
found to work best when the free cyanide is above
one-fourth of the whole in solution. If there is a
greater percentage of free cyanide, less anode sur-
face will be found to work the solution, and if a less
quantity is present, a larger anode will be neces-
sary, and it must be nearer to the articles, or a
strong current must be used.

If the colour of articles after being gilt is acci-
dentally bad, it may generally be improved by
treating with alum, one part; sulphate of zinc, one
part; common salt, one part; and saltpetre, two
parts. This is to be made into a paste with water,
smeared over the articles, and the latter then
heated upon an iron plate and thrown into water.
The surface is then to be scratch-brushed or other-
wise cleaned to bring up the surface. This cannot
be done with articles which are soft-soldered to-
gether. Jewellers generally remedy a bad colour
by applying a paste of borax and water, heating

very highly, and plunging suddenly in water
strongly acidulated with sulphuric acid. But it
will generally be found better, if it can be afforded,
to regild the articles under different conditions of
bath and current.

Bearing upon the colour of gilding is a practice
which is carried on in plating factories by which
copper and silver are dissolved into the solution
from anodes of these metals. But it must be dis-
tinctly understood that solutions so treated are
always kept for such special purposes as render
the introduction of foreign metals necessary.
Common plating solutions would be spoilt by the
treatment. It is not uncommon, for instance, to
work a gilding solution with a copper anode until
a rather red deposit is obtained, when it is replaced
by a gold one of small surface. The temperature
in such cases ought to be high, and the battery
power as much as two cells, as before directed.
When a green gold is required as a standard
colour, work with an anode alloyed with silver.
The green in all gold colour is produced by silver,
and the red of English gold coins by an admixture
of copper.

Anodes.—It is of the highest importance in all
common gilding in cyanide solutions to employ a
gold anode only. The object is, of course, to dis-
solve gold into the solution as fast as it is with-
drawn. Anodes should be sheets of gold for
common work, and they should present as near as
possible a surface as great as that being gilt. If

less surface must be exposed, it may to a certain extent be compensated for by stronger current, or by having the anode and articles nearer together. For special work, such as' the gilding of wires, which are required to be drawn through the liquid regularly, gold strip or wire may be employed as anode surface. The anodes should be of pure gold, especially in the best class of work. A solution is often spoilt by working it with impure anodes. If the anodes are not sufficiently large to have part of their surface above the liquid, they must be hung therein by platinum hooks, or gold wires protected by gutta-percha tubing, or coated with some heat-resisting varnish—otherwise they will be dissolved off and severed at the surface of the liquid, where the free cyanide is present in greatest quantity.

Distance to be Maintained.—It is impossible to give useful figures, so much do the necessary separations vary with the current and solution. The distance is readily ascertained. When the solution is good, temperature high, and current strong, 9 inches may not be too much; if the deposit looks pale at that, decrease the distance.

Time Necessary in Electro-Gilding.—Two or three minutes will usually be sufficient to deposit a very good coating. This also will depend upon the various conditions. The work is usually done too fast. It should be remembered, moreover, that a very little gold will properly protect a large surface, and that the better covering properties of

gold will render unnecessary the laying of such thicknesses as are produced in silver-plating.

Inferior Work, such as the plating of zinc or tin, should always be kept out of the standard bath until these metals have received a deposit of copper in a cyanide of copper solution. (See *Deposition of Copper.*)

Steel and Iron may be gilt in a solution slightly weaker than the standard one. Very little free cyanide of potassium should be present. A weak current will be sufficient.

German-silver should be gilt in a solution having very little free cyanide. "Quicking" should be employed wherever possible before gilding all articles except silver and well-cleaned copper; it insures a good connection between the gilding and the real surface. (See *Preparation.*) Vessels which require only the inside to be gilt, such as cream-jugs, are filled with the gilding solution, with an anode of gold hung in the middle, the other wire from the battery being connected to the vessel itself. When the liquid cannot be held so high in the vessel as to gild its upper edges and the lip, a pad of cotton, thoroughly wetted with the solution and dipping in it, should be led up to the point. If this fails, the anode should be placed upon the pad and the current passed as usual. It is, perhaps, a better way to protect the adjacent parts with a varnish, and to gild in the usual way in the bath.

Free Cyanide in the Solution.—This varies from

causes before mentioned. 'If the colour of the deposit is "foxy,", too much free cyanide may, be suspected. If, however, the colour is pale and weak, and the usual battery power used, too little free cyanide may be suspected. If the anode is dirty, and shows little sign of having been dissolved from, too little cyanide is present. If the anode is very pale, and gas appears to rise from it, too much free cyanide is probably present. The remedy for too little is to supply more, and for too much the solution may be worked with too large an anode, which will give metal to take the excess up, or a little chloride of gold and water may be added to the liquid. (See *Cyanide*, under *Chemicals*.)

Battery Power required.—As a general rule, employ one cell of the Smee or Daniell type, and let its plates be as large as the anodes used in the plating solution. In special cases, which have been indicated before, two cells may be necessary.

Care of Electro-Gilding Solutions.—It is very important that when the plater obtains a good solution he should exert himself to *keep it so*. Contamination direct with such metals as Britannia metal, tin, lead, or zinc, should particularly be avoided.

The Recolouring of Gilt Work.—I am induced to insert here some particulars relating to the recovery of colour in gilded watch-chains, ear-rings, and other jewellery of small bulk. Two or three methods are given in some other books which involve the violent heating of the article, and my

own direct experience has been that such treatment is ruin to a thin coating, although it works on good gold-plating. I treated some gilt chains by the composition and method given by myself, (p. 184) with regard to improving a bad colour, and found the thinner ones spoilt, rendering necessary the overdoing of the gilding.

What is given here may be used for bad colour when it is too pale, but it is more generally applicable to ordinary *gold* chains—not gilded work, although it may be used for both. The first thing to be done is dipping in dilute nitric acid, then in strong nitric acid for an instant only, then in water just before treating as hereafter directed. To produce a

Red Gold, mix together equal parts of copper sulphate, sal-ammoniac, borax, and common alum. Powder together, and moisten with water. This and all the other compositions here given are to be placed in a *plumbago* crucible when required for use. A little water is to be added, and the composition must be made to boil by gentle heat. Tie a horsehair to the work to suspend it with, and dip into the mixture immediately after cleaning, leaving it in for several minutes. Take out, and rinse in a pan of boiling water. At this stage the work should look black, or nearly so; dip in the crucible again until the work is of the desired colour—except for scratch-brushing. Finish by rubbing in the hands with whiting—if a chain—or by scratch-brushing.

For Yellow Gold, use a well-pounded mixture of saltpetre, 6 parts; copperas, 2; white vitriol, 1; alum, 1.

For Green Gold, a well-mixed composition of saltpetre, 5 parts; sal-ammoniac, 5; Roman aloes, 6; verdigris, 5.

In no case is it safe to subject any valuable article to experiments to improve its colour if they involve strong heating or plunging in strong acids. Care should always be taken by the experimenter to note whether the article is soft or hard-soldered. Soft-soldered articles should not, for safety, be heated above the point of boiling water, and greater care generally should be taken with them.

It is not usual to keep gold-plating solutions in the kind of vats used for silver. It is usual to gild in an iron-enamelled tank or pot, and small operations may with every satisfaction be carried on in any convenient glass or porcelain jar or basin of sufficient depth. It is usual in small operations to place the vessel, glue-pot fashion, in another containing water as hot as may be required. Larger vessels of iron are heated direct by gas, lamp, or stove. A constant motion should be given to the articles while gilding. Small articles should be hung together upon a wire, or placed in a platinum basket and kept shaking about in the solution. If the anodes are not pure, but contain silver, they will slowly but surely spoil the solution, which at length will fail to give any but poor and pale, or green, deposits. For this reason the anodes should

be quite pure, to keep the solution in good order.
Water should be added every evening to make up
for that lost by evaporation, and with this water
should be given a little of the potassium cyanide,
to make up for that converted into carbonate of
potassium by exposure to the air. Liquids con-
taining free cyanide are constantly absorbing car-
bonic acid from the air to make the useless car-
bonate of potash. Dust should be kept out of the
solutions, and every evening, or when the work is
done, the whole should be well stirred—the stronger
the solution the greater the necessity for this pre-
caution.

*Recovery of Gold from Spoilt Solutions, Residues,
or Washes.*—When, by accident or constant working
for a long time, a gilding solution becomes deterio-
rated in working value, it may become necessary
to recover the gold from it and make a fresh
solution.

The operation for cyanide solutions must be per-
formed for safety in the open air, or where there is
a good draught. The best way is to precipitate as
much as possible of the gold by adding hydrochloric
acid, with stirring, then heating nearly to boiling.
Allow to cool, pour the liquid portion off, and dry
the precipitate, fusing it afterwards with its weight
of litharge to get rid of contaminating base metals.
The remainder of the solution will probably contain
some gold, which may be thrown down by a few
scraps of zinc.—The dry way is to evaporate off all
the solution by boiling, and drying the residue,

fusing as before' to obtain the gold. After the
fusing, in both cases, it is best to get rid of the
lead and other rubbish by placing the fused mass
in nitric acid. The greatest care is necessary in
all such cases—fusing and precipitating—to avoid
the cyanogen gas given off. The button of gold
obtained by fusing may be rolled or hammered out
to thin sheet to form the new gold chloride.

Waters that have been used in the various opera-
tions of making a solution by the chemical process
should be preserved, and if there is any gold in
them it may be recovered by hanging in them
scraps of zinc, adding a very little sulphuric acid.
In a day or two every vestige of gold will be
thrown down.

Analysis of Gold-plating Solutions.—To ascertain
the quality at any time of a gilding solution, many
methods are adopted by the consulting chemists to
whom such work is usually intrusted. There is no
necessity that the work should go beyond the
plating-room, or from the hands of the plater. I
here give a method which is recommended to
platers in general, the results being certain.

A quantity of the solution is measured and
placed in a porcelain crucible, and slowly evapo-
rated. When the remainder assumes a thick appear-
ance, add a few grammes of litharge, and evaporate
to dryness. Cover the crucible, and raise it to a
red heat for about five minutes. Allow to cool,
and place the fused mass in warm nitric acid to
dissolve out the lead.

Cost of Gold Plating.—Gold may be deposited in the large way, including all working expenses, interest upon capital and losses, at about 5s. an ounce. This is, of course, exclusive of the metal itself. This will vary very considerably in different shops. Gold needs less battery power and time than silver, but an ounce of it covers a much larger surface. Gold-plating, metal included, will be at least ten times as expensive as silver-plating, even although the deposit should be as thin as that usually given by simple-immersion solutions. Such articles as watch cases may be slightly gold-plated, at a cost of about 5s.

CHAPTER VIII.

Deposition of Aluminium.

Its Manufacture from Bauxite. — Aluminium
would form a plating of the greatest value in arts
and manufactures were it practicable to deposit it
like silver or nickel. For many years electro-
platers have expected that something would be
done with it by those who devote their time to
original investigation—true scientific men. In-
formation is, therefore, eagerly sought for. I
attach to my remarks upon what has been done
by others some results obtained by myself in this
direction—not that I wish them to be accepted as
solving the problem, but as a slight advance upon
what had previously been done.

At Salindres, near Alais, is situated a small
factory for the production of aluminium. Bauxite
is heated with soda in an ordinary reverberatory
furnace. The result is aluminate of soda, which is
formed into balls, with an admixture of salt and
coal, and heated to a white heat in vertical retorts
into which chlorine gas is introduced. A double
chloride of soda and alumina distils over, which

is fused with the addition of 35 per cen . of sodium, and 40 per cent. of cryalite as a ·flux. The metal which gathers at the bottom of the crucible is poured into moulds, and is ready for the market. Its production would appear to cost 80 f. per kig. (2·6803 lbs. troy), while it is said that the metal is procurable at 100 f. per kig. ·However this may be, it is certain that the metal costs a great deal more in England, where as much as 10s. per ounce is frequently asked for the sheet and wire. The chloride is procurable at 9d. per ounce, and cheaper for large quantities. Should a large demand arise, the price of aluminium would undoubtedly be very much lower.

A great many of the researches of Bunsen, Sainte-Claire Deville, Duvivier, and others, are in print, but they have little practical value, except as indications that aluminium is exceedingly difficult to deposit as a reguline film.

The patents of Thomas and Tilley were for processes of no value as far as the deposition of aluminium was concerned, although it was claimed that the metal might be deposited from a solution composed of freshly precipitated alumina dissolved in boiling water containing cyanide of potassium; and also from a solution of calcined alum in solution of potassium cyanide. The result is not a deposit of aluminium, but the liberation of hydrogen.

It is also stated that aluminium is deposited from "certain preparations" at a temperature of 500° Fahr., but no particulars are to be had, which renders such statements worse than useless. (See

Chemical News, vol. xxiv. p. 194.) Sprague electrolyzed the solutions spoken of as patented by Thomas and Tilley, and his observation is that ": they do decompose, only, unfortunately, they do not deposit aluminium, but simply give off hydrogen "—this is with six Bunsen cells. He further states his inability to deposit the metal from any of the solutions.

Mr. A. Bertrand gives some particulars of a process by which aluminium may be deposited, from the solution of a double chloride of aluminium and ammonium. It is stated that a clear white deposit is given to a plate of copper, and that it is capable of receiving a very high polish. I have tried the same solution, with more or less salt, and battery power from one Daniell to ten Bunsens, and the best I can obtain is a highly granular and useless deposit, the half of which is not aluminium —gas is given off in abundance, and the process is very wasteful. The deposit is improved by concentrating the solution, and keeping it at a boiling temperature during the operation. The process would appear to be worth experimenting further upon.

I obtained white deposits of aluminium from its sulphate in saturated solution, concentrated and acidulated with a little sulphuric acid. The temperature may be 150° Fahr., or over. The battery power was from two to six Bunsens. It should be remarked that, through some unaccountable defect, the deposit is by no means a certain result of electrolyzing the solution. It would appear that much

power is needed to decompose this solution quickly enough to deposit aluminium. Other salts may be used as well as the sulphate. In all cases the anode should be aluminium, and the battery not less than four Bunsen cells. In some cases a dirty deposit takes place, with no appearance of aluminium in any other condition, and in others 'there appeared under the slimy deposit a thin white coating of the metal, which had good adhesion.

It has been suggested that aluminium might be easily deposited with other metals, such as silver and nickel.

Deposition of Brass.

This process is called *brassing*. It means the coating of metals with an alloy of copper and zinc.

Solutions for Brassing.—Various solutions are in use and have been patented. They all need a current of great strength to decompose them completely. A good solution, used by De Salzede, is made as follows :—Take 25 gals. of water; dissolve a pound of cyanide of potassium (50 per cent.) in a gallon of it; then add 50 lbs. of potassium carbonate, 4 lbs. of sulphate of zinc, and 2 of chloride of copper, to the larger bulk of liquid. Now heat the solution, but not to boiling, until the salts are dissolved, and then stir, adding 25 lbs. of nitrate of ammonium. Allow the liquid to settle for twenty-four hours, and then stir in the cyanide of potassium solution. Allow again to settle, and then draw off the clear portion, which is ready for use. A large

anode of brass must be used, and a powerful cur-
rent is necessary. Two anodes may likewise be
used, one of zinc, and another of copper.

Another solution is made by dissolving 2¼ lbs.
of American potash in 6 gals. of hot water, and
filtering the solution. Also dissolve 2¼ ozs. of
acetate of copper in half a pint of strong liquid
ammonia, and stir it into the first liquid. Then
add 5 oz. of sulphate of zinc, stirring until dissolved,
and finally add 2 oz. of potassium cyanide. Filter
the solution, and when working raise its tempera-
ture to 100° Fahr. The anode must be of brass,
and the current strong.

Another :—Dissolve 10 lbs. of acetate of potas-
sium, the same of acetate of copper, 1 of acetate
of zinc, in 5 gals. of hot water. Prepare a strong
solution of cyanide of potassium, stir it into the
liquid as long as it precipitates and redissolves the
mixture. When all the precipitate has dissolved,
add about one-tenth more of cyanide solution to
form free cyanide. The anode must be brass. Mr.
Wood gives the composition of a good solution :—
Dissolve 1 lb. of potassium cyanide, 2 oz. of
cyanide of copper, and 1 of cyanide of zinc, in
1 gallon of distilled water, and add 2 oz. of sal-
ammoniac. The working temperature is 150° Fahr.,
the anode brass and the battery power about six
Grove's or Bunsen cells. Mr. Watt's formula is as
follows :—Acetate of copper five parts, cyanide of
potassium eight, sulphate of zinc ten, liquid am-
monia forty, and caustic potash seventy-two parts.

Reduce the copper salt to powder, and dissolve it in eighty parts of water, then add twenty of the liquid ammonia. Dissolve the zinc salt in 160 parts of water, at 180° Fahr., and add the remaining twenty of ammonia to it, and stir the mixture strongly. Dissolve the potash in 160 parts of water, and the cyanide in 160 of hot water. Add the solution of copper to that of zinc, then add the caustic potash, and then the cyanide. Dilute the mixture to 8 gals. by adding water, and thoroughly stir the solution. Use a strong battery, add a little ammonia occasionally, and when it works slowly add cyanide of potassium in solution.

A good solution may be made by dissolving, in 1,000 parts of water, twenty-five of copper sulphate, or twelve and a half of copper acetate, and fifteen of fused chloride of zinc. Precipitate the mixture by a solution of 100 parts of carbonate of sodium, and stir the solution. Pour off, and wash the precipitate several times, allowing it to settle each time. Add to the precipitate a solution of fifty parts of bisulphite of sodium, and 100 of carbonate of sodium dissolved in 1,000 of water, and whilst stirring with a wooden rod, add a strong solution of potassium cyanide until the precipitate is just all dissolved, then add three parts more as free cyanide. This is worked by a brass anode, and a current from about six Bunsen cells.

Working Brassing Solutions.—It will be unnecessary to give further examples. Good brass may be deposited from most of the mixtures. Those

with the largest percentage of zinc yield, with a
full current, the poorest brass, and of a pale colour.
The same solutions may, however, be made to give
a deeper-coloured metal by using less battery
power. It is an easy matter to regulate to a nicety
the proportions of zinc and copper in a 'solution'.
If the mixture contains too much zinc, use a copper
anode only until the brass begins to look too red,
when the usual brass anode may be replaced. If
too much copper, and working with a full current,
employ an anode of zinc only until the deposit
begins to look poor and pale. If the current is too
strong, the solution will yield too large a propor-
tion of zinc, and the work will look whitish. But
this will depend greatly upon the proportions of
zinc and copper in solution. If the deposit is too
pale, and the solution with battery power about
right, give motion to the articles, which will cause
the colour to deepen considerably.

It would appear that those solutions containing
ammonia are really the least troublesome, because
they dissolve the zinc from the anode with greater
freedom than the others. In these solutions the
want of ammonia is indicated by there being a
white surface of zinc upon the anode. The plate
should look like brass while working, or a little
paler. Too much ammonia will make it red or
dirty. *Anodes* should be yellow brass of good
quality, or gun metal will work with slightly less
battery power. The surface must be greater than
that being coated. By employing a current of good

strength, no difficulty need be experienced in working these brassing mixtures. They may be kept in order by dissolving more or less of the metal into them by anodes. When this is done along with the other work greater battery power is needed.

Batteries for Brassing.—The currents necessary for working a large bath are so great, that it is doubtful economy to employ the galvanic generator at all. When as many as ten gallon Bunsens are needed in series for the larger operations, and coating of very large work, the expense of nitric acid and zinc, along with the cost of maintenance, would appear to point to the wisdom of using only dynamo-electric machines driven by steam. The first cost would, of course, be much greater, but a remarkable saving would at once be instituted. For baths containing as much as 100 gallons of solution, the battery will frequently need to be as strong as eight or ten Bunsens or Groves. For smaller vats from three to six cells will generally be found enough, but there should be no difficulty in fixing the necessary strength of current for a given surface of anode. The battery plates need not be quite as large as the anode. By a careful system of varying the current, any quality of brass may with the greatest facility be deposited upon the common metals. The ordinary asphaltum vats are in use. Those lined with best Portland cement are probably better, and enamelled iron tanks the best. Wooden tanks are, however, very useful. They must be carefully jointed and bolted.

To Preserve the •Colour of the Deposits, let the articles be, well washed in water, then in water to which some caustic lime has been added, and finally dry in a stove or hot sawdust.

Deposition of Platinum.

Chloride of Platinum is the most common salt, and from this most of the tried solutions have been made. Its price in small quantities is about 24s. per ounce. It is most economically made by dissolving platinum scraps in a mixture of one part nitric acid and two and a half of hydrochloric acid. The mixture must be kept hot, but must not be made to boil. As soon as dissolution is complete, evaporate the mixture slowly, and when nearly dry set aside to cool and crystallize. If the heat has been too great, the salt will be of an olive colour instead of a full rich yellow. It will be nearly red if iridium is present. It is usual to make all the other salts of platinum from this. It should be crystallized if it is to be kept.   .

Sodio-Platinic Chloride is obtainable commercially at about 24s. per ounce. It is usually prepared by adding common salt to a solution of the platinic chloride. It is a yellow salt.

Simple-Immersion Deposition of Platinum.—To obtain a reguline white deposit of platinum is no easy matter. The simple-immersion process may be useful for platinising such things as Smee battery plates, Bunsen carbons, and so on; but there is

very little certainty in obtaining good metal by the simple-immersion process. The deposits *required* upon Smee plates and carbons are highly granular, and are very often black. A solution which may be used for depositing platinum by simple immersion on small articles is made thus:—Dissolve chloride of platinum in water to saturation; add to this carbonate of soda, powdered finely, until the mixture effervesces and ceases to effervesce. Then stir in a little glucose, and finally add as much common salt as will produce a white precipitate. The articles must be immersed in a basket of zinc wire, or any vessel of zinc well perforated. A few seconds are usually enough to produce a deposit. If everything is not right the plating will be of a bad colour, or black. Use hot.

To platinise Smee plates or carbons, prepare a vessel of dilute sulphuric acid 20 per cent. Tie to the plate a slip of zinc, and place the latter in a porous pot filled with liquid within the outer vessel, and let the plate occupy the latter. Drop in a little strong solution of platinic chloride, and stir. As soon as a good coating is seen to form, strengthen the solution by adding a little more platinic chloride. On removal dip in water, and dry spontaneously.

Platinum Solution for Battery Process.—Prepare a solution of the sodio-chloride of platinum, stir in a little oxalic acid, and then enough caustic soda to make the mixture alkaline. This is not the easiest solution to work. Another, recommended by Roseleur, is made by dissolving twelve parts of

dry chloride in 500 parts of'water, and filtering; dissolve also, 100 parts of crystalline phosphate of ammonia in 500 parts of distilled water, and stir it into the platinum solution. 'This·addition will produce a·large· amount of precipitate. Add to the mixture at once a previously prepared solution of 500' parts· of phosphate of soda in 1,000 parts of distilled water, well stir, and boil the solution until there is no odour of ammonia, and its alkaline constituent is neutralized, which will be indicated by the liquid reddening blue litmus-paper. It becomes colourless, and is ready for use—hot. A current from three or four Bunsens will be necessary to work it. The anode should be platinum, but it will not, as in most other solutions, dissolve to make up for loss of metal, so that it is necessary to occasionally refresh the mixture with some chloride of platinum. As yet, no really successful solution for the electro-deposition of platinum has been devised—platinum appears to be too difficultly soluble, and, unlike gold, will not dissolve in cyanide of potassium.

Deposition of German Silver.

German-silver is usually an alloy of copper, zinc, and nickel, which form a very good quality of the metal.

Depositing Solution.—Dissolve good German-silver in nitric acid. Prepare a solution of cyanide of potassium, and·stir into the German-silver mix-

ture slowly, until the whole of the metal 'is pre-cipitated. Then pour off the exhausted liquid, wash the precipitate, and stir into it a strong solution of cyanide•of potassium until it 'is quite dissolved; then a very little more cyanide, and dilute the mixture with twice its bulk of water..

Another solution may be used. Dissolve a pound of each cyanide of potassium·and carbonate of ammonium in a gallon of water.. Heat the mixture to 160° Fahr., and dissolve German-silver into it by means of an anode of German-silver and a receiving plate of brass or copper. Pass a powerful current, such as that from six or eight Bunsens, until a good deal of metal is dissolved in—a bright cathode plate should be introduced occasionally as a test, and when it receives a good deposit the solution is ready to work with a strong current. Its constitution may be varied by adding copper or zinc from copper or zinc anodes. If the deposit is too red, stir in some carbonate of ammonia; if too white, the want of cyanide is indicated.

All solutions made from alloys of this kind require strong currents to decompose them effectually.

Simple-Immersion Nickel Alloy.—I add here a method of plating published in the scientific journals some time ago. Not having tried it myself, I am unable to speak with confidence of the results, but should imagine them to be agreeable to the description.

The alloy is one resembling German-silver, and it is said that the coating is more durable than one

of silver. First melt one part of copper and five of
pure tin—preferably Australian tin. The alloy is
granulated as usual, but not too finely, and then
mixed with water and cream of tartar—as free from
lime as possible—into a paste. To each 200 parts
of the granulated alloy is added 1 part of oxide of
nickel, and the articles to be plated are laid in it.
After boiling for a short time they become "beau-
tifully plated." Some fresh oxide of nickel must, of
course, be added from time to time.

It is said that the brass and copper articles require
little or no previous preparation. Articles of iron
will not coat in it; they must, therefore, be coated
in the usual way, with copper first—in the cyanide
of copper solution, or, cheaper, by the simple-im-
mersion processes before spoken of. (See *Deposition
of Copper*.) By adding some carbonate of nickel to
the nickel bath, or to a common tin bath, and boil-
ing, a coating richer in nickel is obtained, and
darker, varying in colour from that of platinum to
a blue black, according to the amount of nickel salt
added.

Deposition of Zinc.

It does not pay now to deposit zinc by electricity.
The so-called process of "galvanizing" has nothing
to do with electricity. It is simply a coating of zinc
obtained by immersing the previously cleaned iron
articles in a bath of melted zinc—this is better
than the galvanic process as a protection, but it is
more detrimental to the quality of the iron treated.

To Deposit Zinc.—Make up 'a' solution by dissolving 2 oz. of zinc oxide in a gallon of water in which have previously been dissolved 20 oz. of alum. It is used warm or hot. One cell will be sufficient to deposit from it. The anode is zinc, and the whole matter is exceedingly simple. All metals take the coating.

Deposition of Tin.

Tin may easily be deposited by the simple-immersion process:—Dissolve 1 oz. of chloride of tin and 2 lbs. of ammonium alum in 5 gals. of water. Heat the solution to boiling, clean the articles, and immerse, moving about until they are perfectly coated with tin. As the solution becomes exhausted, add a little chloride of tin.

Also:—Dissolve the double chloride of tin and sodium in water to saturation, and then dilute the solution with twice its bulk of water. Articles to be tinned in this solution must be immersed in a zinc basket, or have tied to them chips of zinc.

Small articles are rapidly coated with tin by placing them in a solution of cream of tartar at boiling temperature, and throwing in a quantity of grain tin. The cream of tartar mixture must be strong. It is better to arrange the grain tin in layers upon copper or brass gauze, to place the articles upon such surfaces, and to boil the liquid —it is suited for coating brass and copper articles.

To make the chloride of tin, which should be
freshly prepared, heat some strong hydrochloric
acid, and add to it plenty of grain tin. As soon as
the action entirely ceases, the liquid is a saturated
solution of tin chloride—it may be crystallized, but
it is more convenient to use it as it is. Tin chloride
is also called *stannous* chloride.

Coloured Coatings for Metals.

Solution.—In a quart of pure water dissolve one
ounce of hyposulphite of soda. Stir into this
another solution made by dissolving an ounce of
acetate of lead in a pint of water.

For use, heat the solution in a glass or earthen-
ware pan to about 195° Fahr., and immerse the
metal required to be coloured. The coating is one
of lead sulphide, and its depth of colour will depend
upon the time the metal is immersed. In a few
minutes brass articles of small size may be coated
with any colour, varying from golden yellow to the
tint of clean copper or red gold, to carmine, down
to dark red; from light aniline blue to bluish
white, then to reddish white or brown.

It is not a good plan to plunge the articles into
the solution without previous preparation; it is
by far best to chemically clean them as for plat-
ing (see *Preparation*), and, before dipping in the
colouring liquid, to keep for a few minutes in hot
water, unless, indeed, the coating is to be a very
slight one. Steel and iron articles may also be

treated, and given a fine blue colour without the aid of such great heat as is necessary in "bluing" or oxidizing. Copper articles do not, of course, show the lighter tints. If the cleaning is well done, . the adhesion will be perfect, so perfect indeed that' the burnisher may be used with impunity; but it is not wise to use the scratch-brush. Instead of burnishing, however, the surface may be finished by a soft and smooth buff, which will impart a lasting polish.

The solution will not keep long in the heated state, as it deposits its sulphide upon the vessel's bottom if no metals are present. It is stated that an exceedingly beautiful red and green colouring can be given to brass articles by omitting the lead, and putting in its stead an equal weight of sulphuric acid. If the immersion continues, the red changes to a fine brilliant green, and then to green and brown, with a splendid iris glitter. The coating is very durable, unlike the others, which are best lacquered over with pale lacquer.

Clean brass or copper may be covered with a firmly adherent pure black coating by placing very near to the flames of burning straw—it will not rub off, and may be polished with a soft cloth.

CHAPTER IX.

Dynamo Machine Working.

THE dynamo machine having greatly superseded the voltaic battery in large plating works, a few remarks upon the management of the current may prove useful.

The duty of a dynamo-electric machine absorbing 1 H. P. varies according to the make and conditions of the circuit. 20 oz. of silver per hour is a very usual rate of deposition for such a machine.

If a machine were to deposit 20 oz. of silver per hour, its power upon nickel would probably not exceed 5 oz.; upon copper, 6 or 7 oz.

It may here be remarked that for nickeling solutions the dynamo machine should be wound with finer wire than for silvering, because of the low conductivity of nickel solution. The finer the wire upon the armature of the machine the greater the number of turns. As the electro-motive force of the machine varies as the number of turns of wire (approximately), a machine wound with

fine wire is more suitable for badly conducting solutions.

Electrical Units.—In terms of the electrical units, as expressed in text books of electricity, the electro-motive force of a machine for silvering, should never be less than 2 *volts.* For nickeling the E. M. F. should be as high as 4 or 5 volts.

The volt is nearly equal to the E. M. F. of a Daniell cell of large size. Such a cell would give a current of about an *ampère* (the unit of *current*).

Such a cell would probably have an *internal resistance* of one *ohm*, which is the unit of resistance adopted by electricians.

It is usual for makers of dynamo machines to state the E. M. F. and the resistance of the machine itself, with the current, in ampères, given off at a stated rate of speed.

Current Regulator.—In electro-plating works the current is usually regulated as to strength by inserting lengths of iron or German silver wire in the circuit. These lengths of wire (both iron and German silver are of low conductivity) are generally coiled into spirals, arranged in sets, forming a *resistance frame.* A lever upon the frame enables the plater to insert or withdraw any required resistance without breaking the circuit. Such frames are supplied with all machines used for plating.

The resistance frames are usually employed with machines wound in series, *i.e.* when armature and electro magnet are in the common circuit, the

same or full current passing through both. But
of late machines wound upon a different plan have
been brought into use. These are what are known
as *shunt* wound machines. The electro magnet in
this case is not in the main circuit, but, in a loop
or shunt circuit, so that a portion only of the
current passes through the magnet. In such
machines the resistance is inserted in the magnet
circuit only. A great saving is thereby effected,
and a steadier current obtained. In the series
machines the resistance coils get very hot; in the
shunt machines there is little loss in this way.

Electro Dynamometer.—Electric metres, capable
of indicating the E. M. F. in volts and the current
in ampères are now to be had. The greatest cer-
tainty may in this way be obtained in the treat-
ment of work. The most suitable E. M. F. being
known for a given surface of work, it may be
determined before commencing. What is really
going on in the circuit will then be quite clear.
For example, it is well known that if some kinds
of work (especially steel and iron) be allowed to
remain too long in the solution before it gets
" struck," or coated with the metal, a bad adhesion
is sure to result. This is always due to some fault
in the current (usually too weak a current is the
cause). When the current can be " turned on "
with certainty no such difficulty is met with. Like-
wise, too strong a current may result in a glisten-
ing coating of nickel that will chip off.

When large dynamo machines are to be used,

absorbing several H.P., and supplying a number of vats, the " leads," or conductors, should be as massive as practicable, and if possible of copper.

Burning of the Goods.—When small articles are exposed to a powerful current, they are not properly coated, and have to be removed and re-cleaned before plating. This is caused by too high an E. M. F. Some platers obviate the difficulty by diverting a portion of the current to a wire or two hung to the cathode wire. This, of course, causes a certain loss of both metal and current. It may be obviated by the use of the resistance frame (as far as the metal is concerned).

Bright Nickel Plating.—Work to be nickeled is now almost invariably polished and brought to a fine surface first. The nickel will then need little treatment beyond simple polishing. The preparatory process is especially important, particularly the alkaline cleanings.

Estimation of the Dynamo Current.—The most important matter in connection with dynamo current working is to maintain the electro-motive force or pressure at the correct value. It will, therefore, be useful to tabulate the pressures usually employed in practice in the deposition of the more common metals and alloys. In order to give some idea of the magnitude of the units now employed for this purpose, it may be as well to remember that the volt of pressure is about seven per cent. less than the electro-motive force of a single Daniell cell. A

pair of Smee cells; joined in series, will also exert
an electromotive force of nearly one volt.

<div style="text-align:center">VOLTS OF PRESSURE USUALLY EMPLOYED.</div>

Solution of						Electromotive force in volts.
Copper for plating	.	.	.	.	.	0·6 to 0·8
Ditto for electrotyping	.	.	.	.	.	0·5 ,, 0·7
Ditto cyanide for iron	.,	.	.	.	.	4·0 ,, 8·0
Silver for plating (double cyanide)	.	.	.	1·0 ,, 3·0
Gold (usual solutions)	.	.	.	.	.	0·5 ,, 1·5
Nickel (double sulphate), .	.	.	.	.	0·5 ,, 6·0
Brass (cyanide) .	.	.	.	.	.	5·0 ,, 7·0
Tin . . .	.	.	.	.	.	0·5 ,, 1·0

It should be understood that these figures can
only take account of average conditions. *The re-
sistances in circuit* determine the pressures required.
The table given above is illustrative of the pressures
generally used when the resistances are as low as
can be conveniently arrived at in ordinary working.
In the case of nickel the pressures given, varying
from half a volt to six volts, appear to call for some
explanation.   In nickel plating it is well known
that to secure the first deposit (or to "strike," as it
is termed) a considerable pressure is requisite. This
may require to be as high as five or six volts.   A
torrent of hydrogen is then given off, and the
vehemence of this is generally a guide to the plater
as to whether the work is struck or not.   But as
soon as the first blush of nickel is secured there is
no longer any necessity to maintain the pressure,
which may then with advantage be reduced to one
volt or less.

Current.—The next important matter is that of

the current, or current density.· It has direct ·refe-
rence to the *size* of the objects to be plated. Current
is now always expressed in terms of the ampère.
Thus it is said that the current should be so many
ampères per square foot of surface to be ·plated.
The current may be estimated ·pretty accurately
beforehand for any specified· surface. But a more
reliable guide is furnished by the colour of the
deposit, especially in copper·,brass, and gold plat-
ing. A pale colour indicates too little current,
while a dark colour may show that the current
density is too great. In the first case the deposit
would be brittle; in the second case it would be
granular and porous.

TABLE OF ORDINARY CURRENT DENSITIES.

Solution of					Ampères per sq. foot.
Copper (acid bath)	.	.	.	.	. 5·0 to 10·0
Copper (cyanide bath)	.	.	.	.	. 3·0 ,, 5·0
Silver (double cyanide)	.	.	.	.	. 2·0 ,, 5·0
Gold (chloride in cyanide)	.	.	.	.	. 1·0 ,, 2·0
Nickel (double sulphate)	.	.	.	.	. 6·0 ,, 8·0
Brass (cyanide bath)	.	.	.	.	. 2·0 ,, 3·0

Formerly the " number of gallons in solution ♥ was
the guide when estimating the *size* of the battery ‹
cell. This method was extremely misleading. The
superficial area of the work is the true guide. For-
merly, in battery working the current density could
be roughly calculated by estimating the size of the
cells, or the number of them connected in parallel.
Of late the introduction of both volt and ampère-
meters enables the plater to get his density regu-
lated to a nicety. The density per square foot

should be so small in depositing copper and silver that no hydrogen appears at the anode.

Regulation.—The electromotive force required at the terminals of the plating vat will depend upon three matters. (1) The resistance of the solution. (2) The distance to be traversed by the current between anode and work to be plated. (3) The superficial areas of the work and anode. It is usual to employ a resistance regulator in connection with the dynamo, as already mentioned. By manipulating this in connection with the proper placing of the work in the vat, the correct pressure and current density are quickly arrived at. The volt and ampère metres should be in constant use, chiefly because the solutions are apt to vary in their conducting power. The *current* is usually regulated by some device enabling the operator to shift the brushes upon the commutator of the dynamo. While a shunt or compound dynamo may automatically regulate the *pressure,* no machine hitherto devised regulates the current save by shifting the position of the brushes.

Series Working.—In extensive electro-plating works, especially in America, the working of vats in series is becoming common. It is doubtless more economical than parallel working. If the current in this way has to force its way through several vats arranged in series, like the cells of a battery, it must be proportionally powerful. That is, the pressure must be multiplied by the number of vats in series. In this way dynamos are frequently em-

ployed capable of yielding an electromotive force
of fifty volts.

· *Secondary Circuit of the Vat in Dynamo Work-
ing.*—It is a well-observed fact that a plating vat.
acts as a secondary battery, and accumulates elec-
tricity ; that is, there is always a counter pressure
from the vat. In working with dynamos this
counter pressure may do a great deal of mischief.
The direction of the current given by a dynamo
depends upon the polarity of the magnet. If this
should happen to be reversed, the dynamo would
when next started give a current in the wrong
direction. The feeble residual magnetism of a
dynamo, while it is not in action, is easily des-
troyed and reversed. To overcome this, the earlier
dynamo makers employed various devices to open
the vat circuit automatically upon the stoppage of
the circuit. These arrangements were intended to
obviate the risk of the counter current from the vat
flowing through the coils of the dynamo. Such a
risk may, however, be incurred while the dynamo
is in motion, by the counter pressure of the vats
overcoming the pressure exerted by the dynamo.
Such a contingency might occur in series working.
The risk of reversed polarity is greatest in the case
of using a *series-wound* dynamo. In this class of
machine the whole of the current evolved by the
machine passes around the field magnet.

·*Shunt and Compound Depositing Dynamos.*—The
great fault of the series-wound dynamo is that it
does not regulate the pressure automatically. A

shunt-wound machine tends to effect this. In this class of dynamo the field magnet is wound with so fine a wire that only a portion of the current evolved passes by that path, the main part passing direct through the plating vessel. In a still more improved form of dynamo both the series and the shunt methods of winding are combined. The effect of both these methods of winding (shunt and compound) is to keep the pressure constant, irrespective of the work in circuit.

Management of the Dynamo.—Failure to Start.— In the case of a series-wound dynamo failure to give any current may be due to several causes. The first inference is that the external portion of the circuit is broken, or presents a very great resistance. If this is not the case the fault will probably be found at the brushes. These may not press evenly upon the commutator cylinder, their contact may be too light, or they may be rocked too far on either side of the neutral point. If the resistance in the vat be very high, so as to prevent the machine from evolving any current, it should be momentarily reduced. Failure to start may be due to failure of the residual magnetism, which often occurs in plating shops, by reason of the secondary current from the plating vat. The only remedy for this is to pass a strong current from a battery or another dynamo through the field magnet coils for a moment. The dynamo will then start, but note should be taken of the direction of the circuit it yields.

Faulty Commutator.—In some of the older dy-
namos, wood, ebonite, and asbestos were used in
the insulating of the commutator cylinder.   These
substances are apt to become clogged up with
copper dust.   They then serve to bridge across
metallically from one plate to another.   A dynamo
may from this cause refuse to give any current.
The only remedy is to cut away the faulty separa-
tion.   A dynamo may fail, or partially fail, through
the use of oil about the commutator.   The oil
spreads upon the brushes and so partially cuts off
the current.   The remedy for this is to keep all
oil away from the commutator.   Brushes and all
contact fittings must be kept clean.   A faulty com-
mutator is the cause of most of the trouble experi-
enced by beginners with dynamos.   The brushes
should be properly and squarely trimmed.   They
should be set to bear *lightly* upon the commutator.
The surface of the latter may be lubricated occa-
sionally with the lightest possible touch of vaseline.
Any roughness should be smoothed off by means
of fine glass-paper. Emery polish should be avoided.
If the commutator is well looked after it will acquire
a hard, glossy surface, free from scratches.   Vaseline
should be used but seldom.   In shifting the brushes
to regulate the current, much sparking should be
avoided ; it tends to burn pits in the commutator.
A pit, once started, will gradually become deeper.
A commutator that has become rough and pitted
should be removed from the frame and mounted in
the lathe.   The turner should then take a fine cut

off the surface, using a sharp graver-pointed tool.
The surface-must afterwards be finished to smooth-
ness.

Dynamos and Accumulators.—The secondary bat-
tery, or 'accumulator, has found a place in the work
of electro-plating. In many plating-works the
engine moving the dynamo is only kept at work
during the day. It is therefore impracticable to
carry on the deposition all night as is frequently
required. This has been met by the employment,
in a great many plating-works, of a battery of accu-
mulators. These are charged during the day by the
dynamo. The latter is selected with sufficient power
to both keep the depositing vats going and to also
charge the accumulator. A shunt-wound dynamo is
used for the purpose. The accumulator cells used
are of the largest size. They are grouped usually
in parallel, so that they act as one large cell. In
most operations the pressure exerted by one cell
of an accumulator (about two volts) is sufficient.
When "striking" in nickel-plating two or three
cells may be used, if required, joined in series.

It is usual to group all the switches controlling
the dynamo and accumulators upon a common
board. In such case a switch for throwing two or
more cells into circuit, in series, is a convenient
addition. Accumulators are now frequently used
for working vats ranged in series in the circuit.
The series method of working is said to be very
economical of power.

APPENDIX.

Improvements in Nickel-plating Processes.

THE information given in Chapter VI. is sufficiently complete so far as it goes. Since that portion of the book was written, however, the nickel-plater has been at work, and in several minor, though still important matters, considerable improvements in the processes have been evolved.

Copper Foundation.—One of the chief of these developments refers to the now almost universal preparation of steel and iron work by the deposition thereon of a coating of copper.

The main reason for the employment of copper as a base lies in the well-known difficulty of obtaining a perfectly adhesive or amalgamated deposit of nickel upon either iron or steel. This difficulty has all along been recognised, and here and there astute nickel-platers have for many years prepared their work by the deposition of a preliminary coating of copper. On the other hand, it has long been known that copper could very readily and effectively be deposited upon iron and steel. Its reguline character and tough adhesive qualities are combined with great economy in the expenditure of power in the form of current.

Ever since nickel-plating was introduced it has always been considered a matter of difficulty, if not quite impossible, to obtain a heavy deposit that, at the same time, would exhibit no tendency to strip or scale. For this reason nickel-plating direct upon iron and steel, especially polished steel, has always had the objection of thinness, which, in the final process of polishing the salient, parts of the plated 'article, was apt to be almost completely rubbed away."

It may be said that a mere *blush* of cleanly-deposited copper will form a surface upon which the plater can with confidence throw a heavy deposit of nickel, and that the liability to strip therefrom is extremely small. The advantages of a thick deposit of nickel are that it can be manipulated by the polisher with confidence, and the "life" of the plated article is—and partly from this circumstance—greatly increased. At the present time 90 per cent. of the nickelled cycle work is treated with a preliminary coating of copper.

The Solution.—It is well known that in order to secure a good deposit of tough copper upon steel articles an alkaline solution must be employed. Copper may be deposited upon steel by simply plunging it in an acid solution, but the deposit so obtained is extremely thin and unreliable. The best working solution for dynamo working is composed as follows:—

Dissolve sulphate of copper crystals in the ratio of two pounds of crystals to each gallon of water.

Hot water is to be preferred for this purpose. When cooled, stir in liquid ammonia, of specific gravity 880. There will occur a precipitate. The addition of ammonia must continue until the precipitate is redissolved. This solution of ammonio-sulphate should be of a deep blue colour. The solution must now be treated with cyanide of potassium as follows: Dissolve the cyanide (which should be of at least 90 per cent. purity) in the proportion of two pounds to each gallon of water, to form a separate solution. Stir the cyanide solution into the copper bath carefully until the copper therein has been converted into cyanide of copper (indicated by the change of colour). After this part of the process is complete, add at least one-third more of the cyanide solution to form the working free cyanide. There must not be too great an excess of the free cyanide, otherwise the anodes will be too rapidly attacked in working, and an excess of copper in the bath will result.

Working the Solution.—The above solution can be made to yield good copper at any ordinary temperature, if plenty of current be available. But for everyday working, the most satisfactory plan is to warm the solution to about 120° Fahr. As a copper solution of this kind may be worked in an ordinary galvanized iron tank, the heating may be accomplished by a row of Bunsen gas jets underneath. Or, when steam is available, a coil of copper tubing, through which steam is conducted, may be placed in the bottom of the tank.

The working dynamo current for this solution will vary with the size of the work and bulk of solution. The number of ampères and voltage can be quickly determined. The solution being a good conductor, a low voltage suffices. Satisfactory deposits are procured upon all clean steel work.

It must not be forgotten that the chemically-clean surfaces spoken of in previous chapters (see *Preparation*, p. 21) are an absolute necessity in all work to be coppered for nickelling. The work "got up for plating" is frequently *too finely* polished to receive a satisfactory deposit. In such cases a preliminary roughening is given to the surface by a bristle brush carrying a thin paste of ground pumice. No scratches must be made upon the work, as they are difficult to eradicate in polishing.

Work may be transferred from the cyanide coppering solution direct to the nickel bath (p. 154), provided the copper deposit is satisfactory; but it is advisable to take a dip with all articles into a hot-water tank, in order to maintain the purity of the nickel solution.

The advantages of the double process of plating all steel articles more than compensate for the extra expense and trouble it entails. They may be summed up as follows:—Copper is more perfectly adhesive to steel than nickel. Nickel is more perfectly adhesive to copper than to steel. The result is that a heavy deposit of ductile nickel can easily be secured. The advantages of this in finishing and in the durability of the work are obvious.

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THE END